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National Dioxin Study Tier 4 Combustion Sources: Final Test Report Site 3, Sewage Sludge Incinerator SSI-B

Radian Corp., Research Triangle Park, NC

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16. ABSTRACT

This report summarizes the results of a dioxin/furan emissions test of a sewage sludge incinerator equipped with a wet scrubber system for particulate matter emissions control. The test was the third in a series of thirteen dioxin/furan emissions tests conducted under Tier 4 of the National Dioxin Study. The primary objective of Tier 4 is to determine if various combustion sources are sources of dioxin and/or furan emissions. If any of the combustion sources are found to emit dioxin or furan, the secondary objective of Tier 4 is to quantify these emissions.

Sewage sludge incinerators are one of eight combustion source categories tested in the Tier 4 program. The tested sewage sludge incinerator, hereafter referred to as incinerator SSI-B, was selected for this test after an initial information screening and a one-day pretest survey visit.

Data presented in the report include dioxin (tetra through octa homologue + 2378 TCDD) and furan (tetra through octa homologue + 2378 TCDF) results for both stack samples and ash samples. In addition, process data collected during sampling are also presented.

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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TIER 4 — COMBUSTION SOURCES

Final Test Report — Site 3
Sewage Sludge Incinerator SSI — B

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EPA-450/4-84-014l

FOREWORD

This report is the result of a cooperative effort between the Office of Research and Development's Hazardous Waste Engineering Research Laboratory (HWERL) and the Office of Air Quality Planning and Standard's Monitoring and Data Analysis Division (MDAD). The overall management of Tier 4 of the National Dioxin Study was the responsibility of MDAD. In addition, MDAD provided technical guidance for the source test covered by this report. HWERL was directly responsible for the management and technical direction of the source test.

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1.0 INTRODUCTION

This report summarizes the results of a dioxin/furan[*] emissions test of a sewage sludge incinerator equipped with a wet scrubber system for particulate matter emissions control. The test was the third in a series of thirteen dioxin/furan emissions tests conducted under Tier 4 of the National Dioxin Study. The primary objective of Tier 4 is to determine if various combustion sources are sources of dioxin and/or furan emissions. If any of the combustion sources are found to emit dioxin or furan, the secondary objective of Tier 4 is to quantify these emissions.

Sewage sludge incinerators are one of eight combustion source categories tested in the Tier 4 program. The tested sewage sludge incinerator, hereafter referred to as incinerator SSI-B, was selected for this test after an initial information screening and a one-day pretest survey visit.

This test report is organized as follows: A summary of test results and conclusions is provided in Section 2.0, followed by a detailed process description in Section 3.0. The source sampling and analysis plan is outlined in Section 4.0, and the dioxin test data are presented in Section 5.0. Sections 6.0 through 9.0 present various testing details. These include descriptions of the sampling locations and procedures (Section 6.0), descriptions of the analytical procedures (Section 7.0), and a summary of the quality assurance/quality control results (Section 8.0). The appendices contain data generated during the field sampling and analytical activities.

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[*] The term "dioxin/furan" and the acronyms PCDD and PCDF as used in this report refer to the polychlorinated dibenzo-p-dioxin and dibenzofuran isomers with four or more chlorine atoms.

2.0 SUMMARY AND CONCLUSIONS

2.1 SOURCE SAMPLING AND ANALYSIS OVERVIEW

The host plant (Site SSI-B) is a large municipal wastewater treatment plant that operates several multiple hearth sewage sludge incinerators. The incinerator tested is one of two identical units built in 1983. A simplified diagram of the multiple hearth incinerator/wet scrubber system tested is shown in Figure 2-1.

Sampling for dioxin emissions was performed at the scrubber exhaust stack during each of three test runs conducted between November 15 and 19, 1984. All of the field sampling was performed by Radian Corporation. The gaseous, liquid, slurry, and solids sampling that was performed is summarized in Table 2-1. Dioxin sampling at the scrubber exhaust stack was based on the Modified Method 5 (MM5) sampling protocol developed by the American Society of Mechanical Engineers (ASME) for measuring emissions of chlorinated organic compounds. The MM5 train components and train rinses were analyzed by EMSL-RTP and ECL-Bay St. Louis, two of three EPA laboratories collectively known as Troika. The dioxin/furan analyses quantified 2378-TCDD* and the tetra- through octa-dioxin/furan homologues present in the samples.

Sludge feed samples were obtained directly from the incinerator feed conveyor during the test. Analyses for dioxin/furan precursors were performed by Radian on the sludge feed samples. The specific dioxin/furan precursors analyzed for included chlorophenols, chlorobenzenes, polychlorinated biphenyls (PCB), and total chlorine.

Continuous emissions monitoring (CEM) for CO, CO_2, total hydrocarbons (THC), NO_x, and O_2 was performed at the incinerator outlet. Bottom ash samples were taken during each test run for dioxin/furan analysis. Scrubber system blowdown slurry samples were also taken, and the samples were filtered to separate the solids from the aqueous filtrate. The filtrate was analyzed

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*The terms TCDD and TCDF as used in this report refer to tetrachlorodibenzo-p-dioxin and tetrachlorodibenzofuran respectively. The acronyms PCDD and PCDF as used in this report refer to dioxin and furan homologues with four or more chlorine atoms.

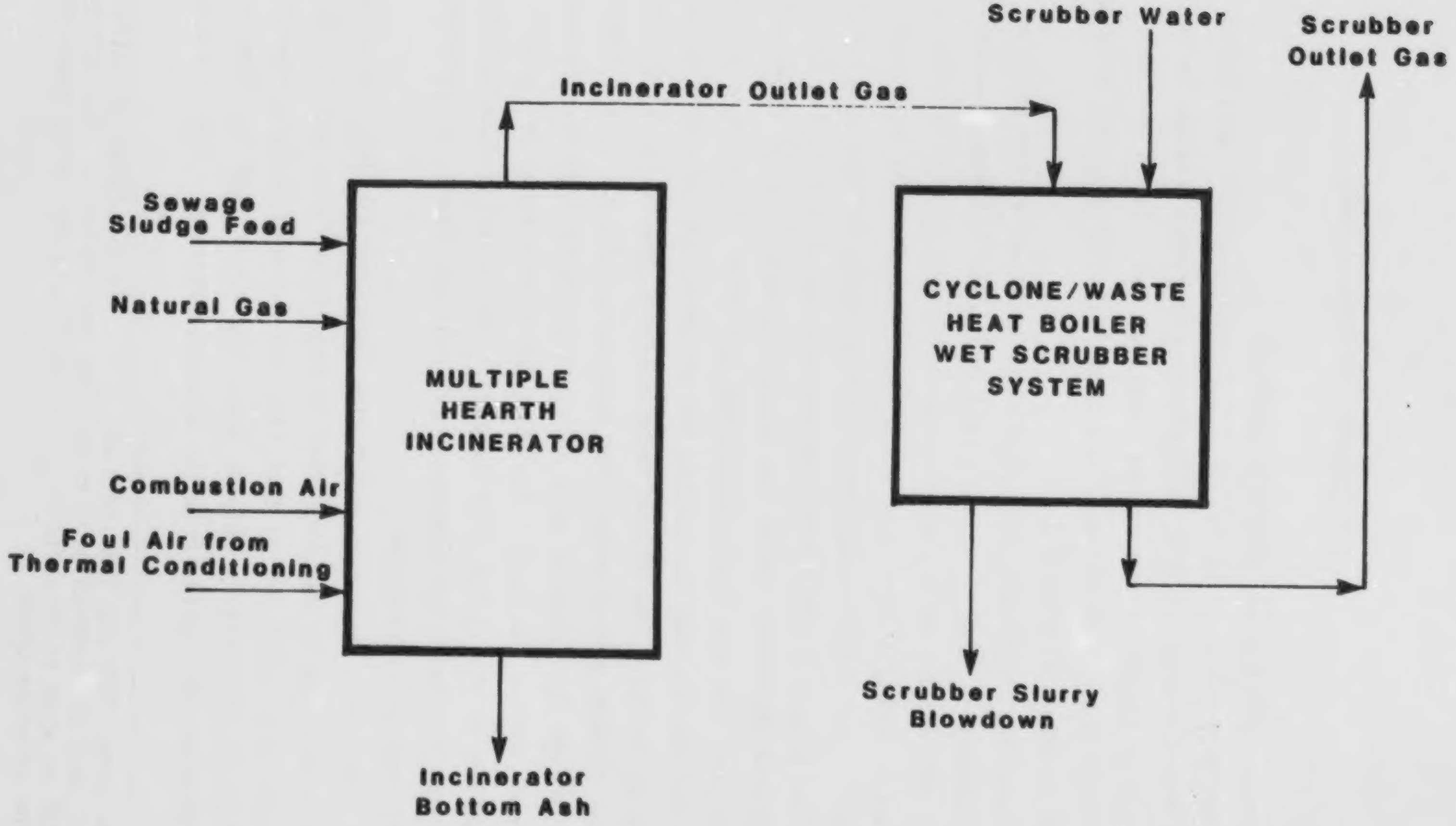
Sewage Sludge Feed
Natural Gas
Combustion Air
Foul Air from Thermal Conditioning
MULTIPLE HEARTH INCINERATOR
Incinerator Outlet Gas
Incinerator Bottom Ash
Scrubber Water
CYCLONE/WASTE HEAT BOILER WET SCRUBBER SYSTEM
Scrubber Outlet Gas
Scrubber Slurry Blowdown

Figure 2-1. SIMPLIFIED FLOW DIAGRAM OF THE SEWAGE SLUDGE INCINERATOR/WET SCRUBBER SYSTEM AT SITE SSI-B

TABLE 2-1. SOURCE SAMPLING AND ANALYSIS OVERVIEW

Item	Item Description
1. Number of test runs	- Three identical test runs (Runs 1,3,5)[a]
2. Gaseous sampling	- MM5 sampling at scrubber outlet (Runs 1, 3,5). Dioxin/furan analysis. - Continuous CO, CO_2, O_2, NO_x, and THC monitoring at incinerator outlet (Runs 1,3,5). - EPA Reference Methods 2,3, and 4 at scrubber outlet (Runs 1,3,5)
3. Liquid and slurry sampling	- Scrubber system blowdown sampling/filtration (Runs 1,3,5). Dioxin/furan analysis.
4. Solids sampling	- Sludge feed sampling (Runs 1,3,5) Dioxin/furan precursor analysis. - Incinerator bottom ash sampling (Runs 1,3,5). Dioxin/furan analysis. - Soil sampling (one composite sample from 10 locations). Potential dioxin/furan analysis.

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[a] Test run 2 was invalidated due to sampling malfunctions; test run 4 was aborted due to unrepresentative process operation.

for dioxin/furan content. Soil samples were also collected for potential dioxin/furan analysis.

2.2 SUMMARY OF RESULTS

Figure 2-2 summarizes test results for Site SSI-B. According to plant personnel, the incinerator and wet scrubber system operated under conditions representative of normal operation during the sampling periods. The average sludge feed rate (wet basis) was 6.3 Mg/hr (6.9 TPH), and the average solids content of the sludge was 36.2 wt%. The maximum hearth temperature in the furnace was approximately $870^{o}C$ ($1600^{o}F$). The average total pressure drop of the wet scrubber system was 34.8 inches of H_2O. The average exhaust gas temperature from the scrubber system was $22^{o}C$ ($71^{o}F$). As shown in Table 2-2, the 2378-TCDD isomer was not detected in stack gas emissions from the scrubber. Average as-measured stack gas concentrations of total PCDD and total PCDF at the scrubber exhaust outlet were 0.33 ng/dscm and 5.59 ng/dscm, respectively. The average hourly emissions rates at the scrubber exhaust outlet were 11.6 ug/hr for total PCDD and 194 ug/hr for total PCDF. The tetra-chlorinated and octa-chlorinated dioxin homologues were the largest contributors to the total PCDD emissions and the tetra-chlorinated furan homologue were the largest single contributor to the total PCDF emissions.

At the scrubber exhaust stack, the measured flue gas flow rate was 582 dscmm (20,600 dscfm) at a temperature of $77^{o}C$ ($170^{o}F$). Average flue gas concentrations measured at the incinerator outlet by the Radian continuous emissions monitoring system were: O_2, 13.1 volume percent; CO, 4676 ppmv @ 3 percent O_2; CO_2, 18.9 volume percent @ 3 percent O_2 (dry); NO_x, 523 ppmv @ 3 percent O_2 (dry); and THC, 28 ppmv @ 3 percent O_2 (wet).

Samples of bottom ash from the multiple hearth incinerator did not contain detectable levels of the 2378-TCDD isomer. The bottom ash samples contained 0.01 ppb and 0.042 ppb of total PCDD and total PCDF, respectively.

Precursor analysis of the sludge feed detected 0.03 ppm of chlorobenzenes, but PCB's and chlorophenols were not detected. Total chloride analysis of the sludge feed detected 21.4 ppm total chlorides. The composite soil sample for Site SSI-B has not yet been analyzed for dioxin/furan content.

Incinerator Operating Data Ⓖ

Wet Sludge Feed Rate	6.9 TPH
Wet Sludge Solids	36.2 wt%
Dry Sludge Volatiles	74.7 wt%
Flue Gas Oxygen	16.5 vol%

Sludge Feed Precursor Data Ⓐ

Chlorobenzenes	0.03 ppm
PCB's	ND
Chlorophenols	ND
Total Chlorides	214 ppm

Bottom Ash Dioxin/Furan Data Ⓒ

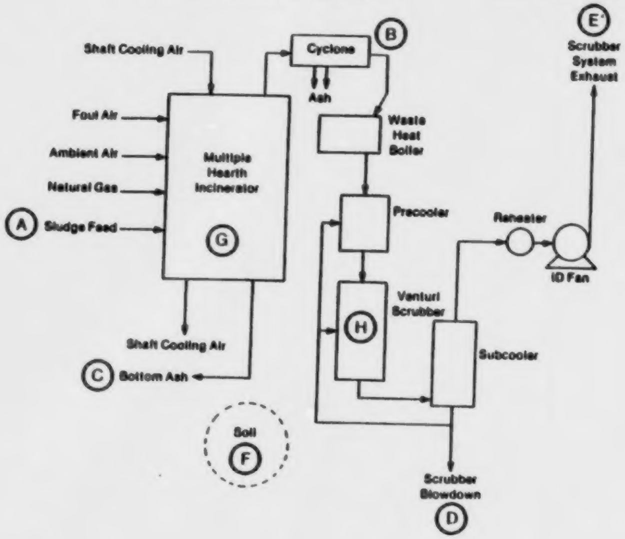
Species	Concentration[a] (ppb)
2378-TCDD	ND
Total PCDD	0.01
Total PCDF	0.042

[a]Average of three test runs.
ND - Not detected.

Continuous Monitoring Data[a] Ⓑ

O_2	13.1 vol%
CO	4676 ppmv
CO_2	18.9 vol%
NO_x	523 ppmv
THC	28 ppmv

[a]Values corrected to 3% oxygen.


Shaft Cooling Air
Cyclone
Ash
Ⓑ
Foul Air
Ambient Air
Natural Gas
Ⓐ Sludge Feed
Multiple Hearth Incinerator
Ⓖ
Waste Heat Boiler
Precooler
Venturi Scrubber
Ⓗ
Subcooler
Reheater
ID Fan
Ⓔ
Scrubber System Exhaust
Shaft Cooling Air
Ⓒ Bottom Ash
Soil
Ⓕ
Scrubber Blowdown
Ⓓ

Soil Dioxin/Furan Data Ⓕ

Analyses not yet performed.

Scrubber Outlet Dioxin/Furan Emission Data Ⓔ

Species	Concentration[a] (ng/dscm)	Emission Rate (ug/hr)	Emission Factor[b] (ug/kg)
2378-TCDD	ND	ND	ND
Total PCDD	1.60	11.6	0.048
Total PCDF	27.9	194	0.83

[a]Flue gas concentration data corrected to 3% O_2. Average of three test runs.
[b]Emission factor based on dry sludge feed rate.
ND - not detected.

Scrubber Outlet Flue Gas Parameter Data Ⓔ

Temperature	77°C
Moisture	3.72 vol%
Flowrate	502 dscmm (dry) 736 acmm (actual)

Scrubber Blowdown Filtrate Dioxin/Furan Data Ⓓ

Species	Concentration[a] (ng)
2378-TCDD	ND
Total PCDD	ND
Total PCDF	1.3

[a]Average of two test runs. Approximately 16 liters of scrubber blowdown water were filtered each run.
ND - Not detected.

Scrubber Operating Data Ⓗ

Cyclone P	4.7 inches H_2O
Venturi P	25.1 inches H_2O
Subcooler P	5.0 inches H_2O
Venturi Water Flowrate	189 gpm
Subcooler Outlet Temperature	71°F

Figure 2-2. Data Summary for Site SSI - B

TABLE 2-2. SUMMARY OF MEAN DIOXIN AND FURAN EMISSIONS DATA FOR SITE SSI-B

Parameter	2378 TCDD	Total PCDD	Total PCDF
Emissions Concentration (ng/dscm)			
As-measured	ND	0.33	5.59
Corrected to 3% O_2	ND	1.60	27.9
Emissions Rate (ug/hr)	ND	11.6	194

3.0 PROCESS DESCRIPTION

The wastewater treatment plant and sewage sludge incinerator tested at Site SSI-B are described in this section. The description includes a discussion of the heat recovery and air pollution control systems associated with the incinerator.

3.1 TREATMENT PLANT

Site SSI-B is a large municipal wastewater treatment plant that operates several multiple hearth sewage sludge incinerators. Plant influent consists of approximately 25 percent industrial waste and 75 percent domestic sewage. Based on plant data, there are no known large sources of potential dioxin precursors (e.g., chlorophenols, chlorobenzene, PCB, etc.) in the plant influent.

A wastewater treatment and sludge processing flow diagram for the facility is shown in Figure 3-1. Treatment of the wastewater includes screening, grit removal, primary sedimentation, aeration for biological treatment (activated sludge), secondary sedimentation, and chlorination. The treatment plant effluent is discharged into a river. Since this study, dechlorination facilities have been added to the plant.

Primary and secondary sludges are processed according to the diagram in Figure 3-1. Most of the primary sludge is gravity thickened and conditioned with polymer. All of the secondary sludge and the remainder of the primary sludge are combined in a 3:1 ratio prior to thermal conditioning. Thermal conditioning oxidizes and breaks down the solids-water bond in the sludge which allows for improved dewatering. The polymer-conditioned primary sludge and the thermally conditioned primary/secondary sludge blend are sent to a holding tank and then dewatered on roll presses. Use of roll presses at Site SSI-B results in a drier sludge feed cake than that obtained at most facilities using either filter presses or vacuum filters. The blended, dewatered sludge is burned in the multiple hearth incinerators.

3.2 INCINERATOR DESCRIPTION

The incinerator tested at Site SSI-B is one of two identical Envirotech nine-hearth sewage sludge incinerators that were installed at the plant in

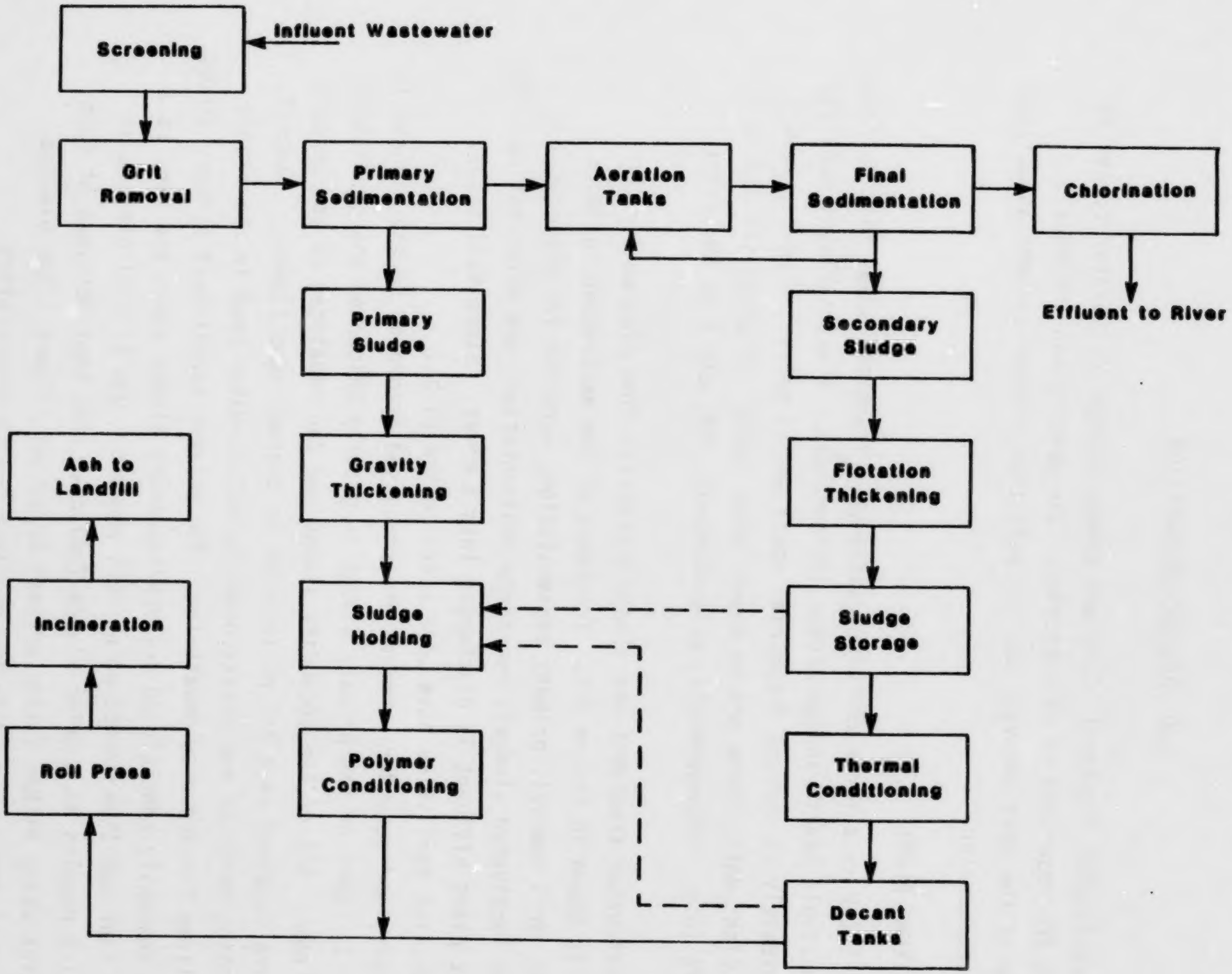

Screening
Influent Wastewater
Grit Removal
Primary Sedimentation
Aeration Tanks
Final Sedimentation
Chlorination
Effluent to River
Primary Sludge
Secondary Sludge
Ash to Landfill
Gravity Thickening
Flotation Thickening
Incineration
Sludge Holding
Sludge Storage
Roll Press
Polymer Conditioning
Thermal Conditioning
Decant Tanks

Figure 3-1. WASTEWATER TREATMENT AND SLUDGE PROCESSING FLOW DIAGRAM FOR SITE BSI-B.

1983. A schematic diagram of the incinerator tested and its heat recovery and air pollution control systems is shown in Figure 3-2. Table 3-1 lists some of the more important design parameters of the incinerator.

Conditioned primary and secondary sludge with a solids content of 30 to 40 percent by weight is fed to the second hearth of the incinerator (hearth one) at a rate of about 2.3 to 2.7 dry Mg (2.5 to 3.0 dry tons) per hour. The design capacity of the incinerator is 3.39 dry Mg (3.75 dry tons) per hour. The sludge typically has a volatiles content of 65 percent by weight (dry solids basis) and a heating value of 24.4 J/g (10,500 Btu/lb) of volatiles. The upper hearths are used for drying of the sludge cake, the middle hearths are used for burning, and the bottom hearths are used for ash cooling.

An auxiliary fuel system consisting of natural gas-fired burners is available to provide supplemental heat when necessary. However, efforts by plant personnel to minimize energy usage usually results in these burners being used only during incinerator startup. Incinerator SSI-B also has the capability of firing scum from the wastewater treatment process, but scum was not fired during the test program. Ordinarily, all the scum produced by the plant is fired in a dedicated scum incinerator. The scum incinerator is never used to burn sludge and was not part of the test program. Combustion air for Incinerator SSI-B consists of ambient air and odorous air collected from ventilation systems on various wastewater treatment plant processes, including thermal conditioning. A shaft cooling air system is used to prevent overheating of the rabble arm shaft. The shaft cooling air exhaust is vented directly to the atmosphere via a stack separate from that used for the incinerator air pollution control system. None of the shaft cooling air exhaust is recycled for use as combustion air.

Incinerator SSI-B is typically operated to maintain a temperature of 870°C (1,600°F) on Hearth No. 3 (fourth hearth from the top). The temperature is controlled by a microprocessor-based system that varies the combustion air intake dampers. The percent oxygen in the incinerator exhaust gas is typically 12 to 15 percent.

Under normal feed rate conditions, Incinerator SSI-B produces about 22 Mg (20 tons) per day of bottom ash, which is pneumatically conveyed to silos for storage. The ash is ultimately loaded onto trucks or rail cars and hauled away for land disposal.

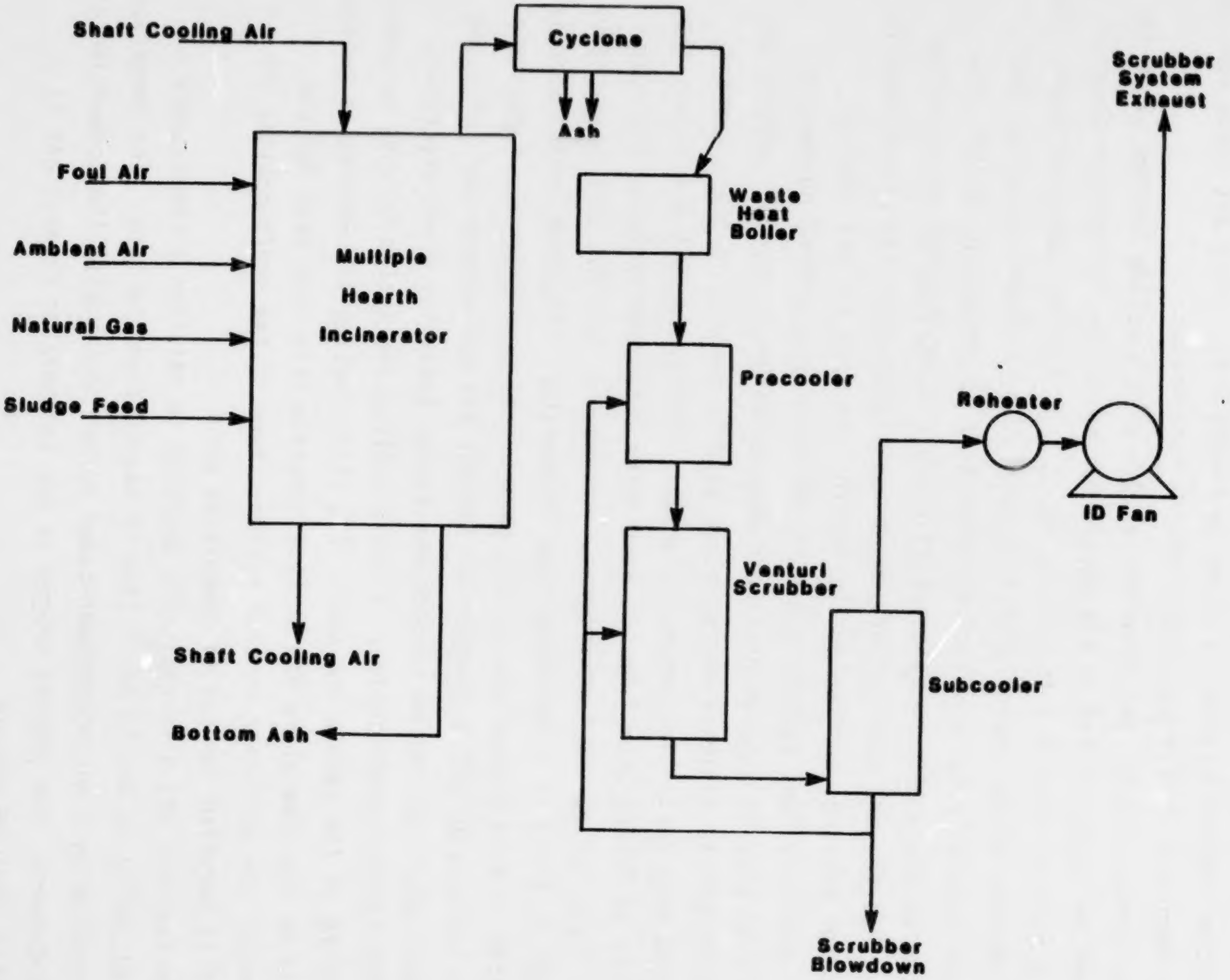

Shaft Cooling Air
Foul Air
Ambient Air
Natural Gas
Sludge Feed
Multiple Hearth Incinerator
Shaft Cooling Air
Bottom Ash
Cyclone
Ash
Waste Heat Boiler
Precooler
Venturi Scrubber
Subcooler
Scrubber Blowdown
Reheater
ID Fan
Scrubber System Exhaust

Figure 3-2. SCHEMATIC DIAGRAM OF INCINERATOR SSI-B AND ASSOCIATED AIR POLLUTION CONTROL EQUIPMENT

TABLE 3-1. INCINERATOR AND SLUDGE DESIGN PARAMETERS FOR INCINERATOR SSI-B

Design Parameter	Value
Incinerator	
1. Manufacturer	• Envirotech
2. Number of Hearths	• 9
3. Sludge burning capacity	• 3.75 tons/hr (dry)
4. Exhaust gas volume	• 82,000 acfm @ 1,200^{o}F
5. Bottom ash production	• 28 tons/day (typical) • 34 tons/day (maximum)
6. Auxiliary fuel	• Natural gas (startup only)
Sludge Feed	
1. Sludge type	• Conditioned and dewatered primary and secondary sludge
2. Solids content	• 30% to 40%

3.3 HEAT RECOVERY AND AIR POLLUTION CONTROL SYSTEMS FOR INCINERATOR SSI-B

The exhaust gas train for Incinerator SSI-B consists of a quad cyclone, a waste heat recovery boiler, a wet scrubber system, an induced draft fan, and an exhaust stack. Table 3-2 gives design parameters for some of these devices. The heat recovery and air pollution control system components are described below.

3.3.1 Quad Cyclone

The quad cyclone is used for large particulate removal prior to the waste heat boiler system. The cyclone has a rated gas flow capacity of 38.7 m^3/s @ 650^{0}C (82,000 acfm @ 1,200^{0}F) and typically operates at a pressure drop of 1.2 kPa (5 inches of water). The rated particulate matter removal efficiency of the cyclone is 72 percent. Uncontrolled particulate matter emissions entering the cyclone are estimated to be approximately 617 Mg (680 tons) per year.

3.3.2 Waste Heat Recovery Boiler

The waste heat boiler recovers heat from the incinerator offgas to produce steam. The nominal steam capacity of the boiler is 8200 kg/hr @ 2.8 MPa (17,000 lb/hr steam @ 400 psig). The steam is used in the thermal conditioning process and for other auxiliary equipment such as steam turbines. Waste heat boiler offgas is sent to the wet scrubber system at a temperature of about 230^{0}C (490^{0}F).

3.3.3 Wet Scrubber System

The wet scrubber system consists of a precooler, a venturi scrubber, and a packed tower subcooler with demister (Figure 3-3). Subcooler exhaust is reheated and discharged to a stack. In the precooler, blowdown water from the subcooler is sprayed into the gas stream to provide cooling from about 254^0 to 80^{0}C (490^{0}F to 180^{0}F). The design precooler water flow rate is 136 m^3/hr (600 gpm). Precooler exhaust gas enters the venturi scrubber, which is operated at a pressure drop of about 5.0 to 7.5 kPa (20 to 30 inches of water). Blowdown water from the subcooler is injected at the venturi scrubber throat at a design rate of 114 m^3/hr (500 gpm). Design gas flow through the venturi scrubber is about 16.5 m^3/s @ 80^{0}C (35,000 acfm @ 180^{0}F), and the water:gas ratio is on the order of 1.3 m^3 per 1000 m^3 (10 gallons per 1,000 acf). The rated particulate matter removal efficiency of the venturi scrubber is 99 percent. Gas exits the scrubber at about 80^{0}C (160^{0}F) and is sent to the

TABLE 3-2. DESIGN DATA FOR INCINERATOR SSI-B AIR POLLUTION CONTROL SYSTEM

System Component	Inlet Gas Flow (acfm @ T, °F)	Maximum Water Flow (gpm)	Particulate Removal Efficiency (%)	Pressure Drop P (in H_2O)	T in (°F)	T out (°F)
Quad cyclone	82,000 acfm @ 1,200°F	-	72	5	1,200	ND[a]
Precooler	58,000 acfm @ 490°F	600[b]	ND[a]	0.05	490	180
Venturi scrubber	35,000 acfm @ 180°F	500[b]	99	33	180	160
Subcooler	34,000 acfm @ 160°F	2,000	ND[a]	3.0	160	100

[a] ND = no data available.

[b] Precooler water and venturi scrubber water consists of subcooler blowdown.

[c] Subcooler makeup water consists of nonpotable wastewater treatment plant effluent.

subcooler, which consists of a three-tray packed tower with a demister. Fresh makeup water (wastewater treatment plant effluent) is added to the subcooler at a design rate of 454 m^3/hr (2,000 gpm). Actual water flow rates and gas flow rates during normal operation are generally 50 to 80 percent of the design rates. The offgas temperature from the subcooler is about 22°C (71°F). Blowdown water from the subcooler is partially recycled to the precooler and venturi scrubber, with the remainder sent to a drain. The solids content of the subcooler blowdown streams is estimated to be on the order of 40 mg solids/liter (3.4×10^{-4} lb solids/gal).

Offgas from the subcooler is reheated with steam and discharged to a stack using an induced draft fan. The exhaust stack diameter is 0.8 m (2.5 feet), and the stack discharge is 27 m (90 feet) above the ground. Measured particulate matter emissions at the exhaust stack during the initial performance test for the incinerator were 0.20 g/kg (0.40 lb/ton) dry sludge solids, or about 0.8 kg/hr (1.7 lb/hr).

3.4 PROCESS DATA MONITORED

Process data monitored by the plant include data on both the incinerator and the air pollution control system. The incinerator operating data include wet sludge feed rate (lb/hr), sludge solids content (weight %), hearth temperatures (°F), and auxiliary fuel usage (scf). The air pollution control system data include temperatures and pressure drops, (°F, inches of H_2O) for the cyclone, precooler, venturi scrubber, and subcooler. Water flow rates for the precooler, venturi scrubber, and subcooler are also monitored. These data are maintained in daily logbooks and summarized on a monthly basis using a computer.

4.0 TEST DESCRIPTION

This section describes the field sampling, process monitoring, and analytical activities that were performed at Site SSI-B. The purpose of this section is to provide sufficient descriptive information about the test so that the test data presented in Section 5.0 can be easily understood. Specific testing details (specific sampling locations and procedures) are presented in Section 6.0.

This section is divided into three parts. Section 4.1 summarizes field sampling activities, Section 4.2 summarizes process monitoring activities, and Section 4.3 summarizes analytical activities performed during the test program.

4.1 FIELD SAMPLING

Table 4-1 shows the source sampling and analysis matrix for Site SSI-B. Five sets of dioxin/furan emissions tests were performed on consecutive days at the scrubber outlet sampling location. This location is shown as Point E in Figure 4-1. Dioxin/furan sampling was based on the Modified Method 5 (MM5) sampling protocol developed by the American Society of Mechanical Engineers (ASME) for measuring emissions of chlorinated organic compounds. Sampling was performed isokinetically for a minimum of 4 hours. A total of five MM5 test runs were performed at Site SSI-B. However, the second test run was invalidated because the filter popped up from the teflon frit during the test run and the fourth test run was aborted after completion of 13 of 24 traverse points due to extended non-representative incinerator operation.

Continuous emissions monitoring (CEM) of O_2, CO, CO_2, NO_x, and total hydrocarbons (THC) was performed during the MM5 test runs. These data were obtained to assess variations in combustion conditions during the sampling periods. Instantaneous concentrations of each species monitored were determined and recorded every five minutes by the CEM system.

Three types of process samples were taken during the MM5 test periods: sewage sludge, bottom ash, and scrubber blowdown. The sewage sludge samples were taken to characterize the dioxin/furan precursor contents of the materials fed to the incinerator. These samples were taken on an hourly

TABLE 4-1. SOURCE SAMPLING AND ANALYSIS MATRIX - PLANT SSI-B

Sample Location	Sample Type or Parameter	Sampling Method	Analysis Method	Number of Samples or Frequency
Outlet exhaust stack (point E on Figure 4-1)	Dioxin and furan	Modified EPA Method 5 (MM5)	Gas chromatograph/mass spectrometer	Five test runs[a]; one per test day.
	Volumetric flow	EPA Method 2	NA[b]	Once per MM5 test run.
	Molecular weight	EPA Method 3	Gas chromatograph/thermal conductivity detector	Two integrated bag samples per MM5 test run.
	Moisture	EPA Method 4	Gravimetric balance	Once per MM5 test run.
Incinerator outlet location (point B on Figure 4-1)	CO/CO_2	In-stack filter probe and heat-traced teflon line	Nondispersive infrared analysis	Continuously during MM5 test runs.
	O_2	Same as CO/CO_2	Paramagnetic analzer	Continuously during MM5 test runs.
	NO_x	Same as CO/CO_2	Chemiluminescent analyzer	Continuously during MM5 test runs.
	THC	Same as CO/CO_2	Flame ionization analyzer[c]	Continuously during MM5 test runs.
Sludge feed	Dioxin precursors	Grab samples	Gas chromatograph/mass spectrometer	Duplicate composite samples for each test run.
Bottom ash	Dioxin and furan	Grab samples	Gas chromatograph/mass spectrometer	Duplicate composite samples for each test run.
Scrubber blowdown	Scrubber blowdown solids for dioxin and furan	Pressure filtration	Gas chromatograph/mass spectrometer	One composite sample per MM5 test run.
	Scrubber blowdown filtrate for dioxin and furan	Pressure filtration	Gas chromatograph/mass spectrometer	One composite sample per MM5 test run.
	Scrubber blowdown for weight percent solids	Vacuum filtration	Gravimetric balance	One composite sample per MM5 test run.
Soils	Dioxin and furan	Grab samples	Gas chromatograph/mass spectrometer	One composite of 10 samples.

---

[a] The second test run was invalidated because the filter popped up from the teflon frit sometime during the sampling run. The fourth test run was aborted due to large fluctuations in sludge composition and moisture content that led to extended non-representative operation of the incinerator.

[b] NA = not applicable.

[c] The flame ionization analyzer was calibrated using propane standards.

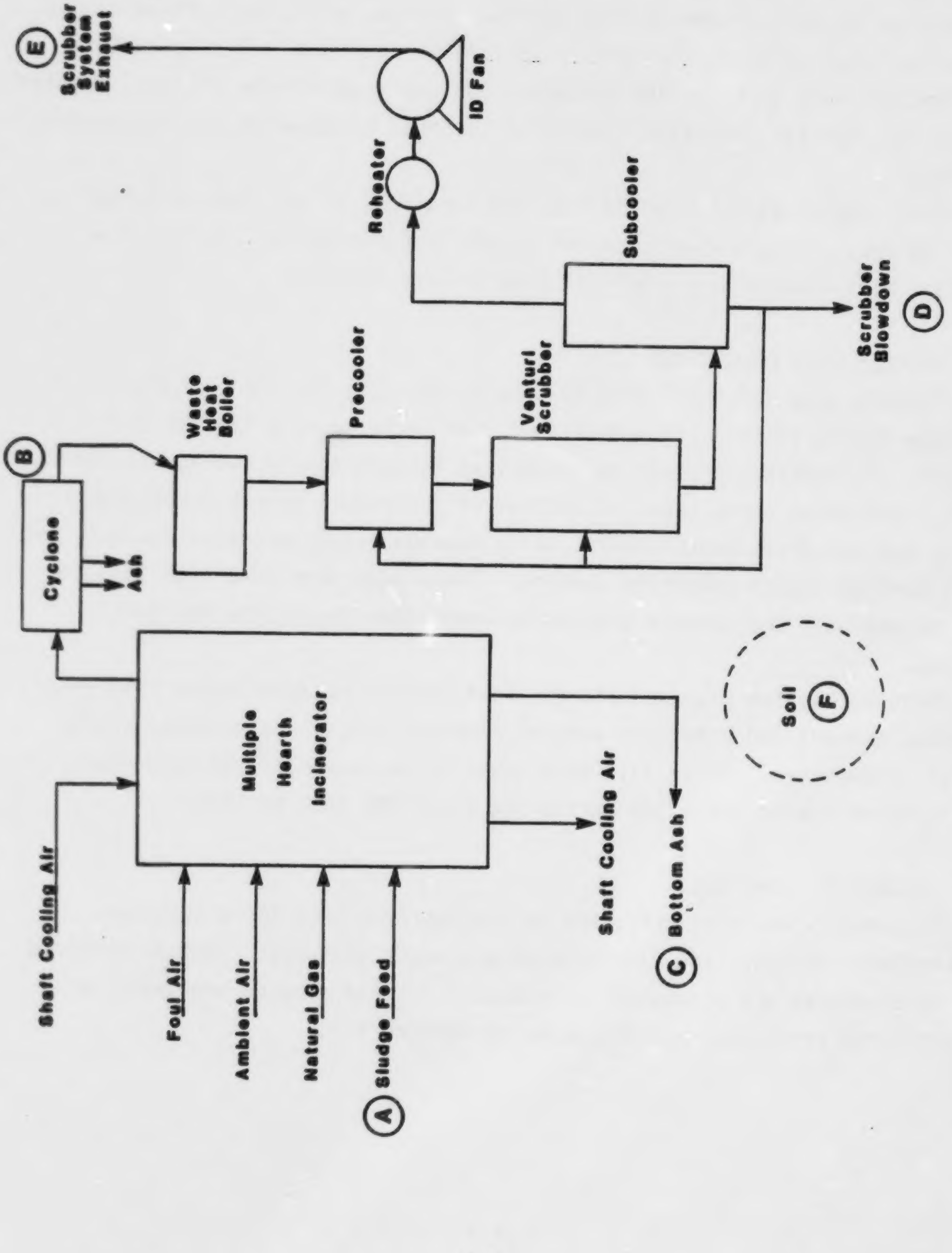

Shaft Cooling Air
Foul Air
Ambient Air
Natural Gas
A
Sludge Feed
Multiple Hearth Incinerator
Shaft Cooling Air
C
Bottom Ash
Cyclone
Ash
B
Waste Heat Boiler
Precooler
Venturi Scrubber
Subcooler
Scrubber Blowdown
D
Reheater
ID Fan
E
Scrubber System Exhaust
Soil
F

Figure 4-1. SAMPLE POINT DIAGRAM FOR SITE SSI-B.

basis, and individual composite samples were prepared for each test run. The bottom ash and scrubber blowdown samples were taken to determine the potential for using dioxin/furan analyses of these materials as indicators of the presence or absence of dioxin/furan in the flue gas emissions. These samples were also taken on an hourly basis. Individual composite ash samples were prepared for each test run and scrubber blowdown samples were filtered on-site to provide separate composite samples of scrubber blowdown solids and aqueous filtrate.

Soil samples were collected from ten locations at the plant site and combined into a single composite, which was transferred to Tier 7 of the National Dioxin Study for potential dioxin/furan analysis.

4.2 PROCESS DATA COLLECTION

Process data were collected on-site to characterize the operation of the multiple hearth incinerator and wet scrubber system during the MM5 test periods. Incinerator process data obtained include hourly average sludge feed rates, continuous strip chart recordings of individual hearth temperatures, hourly furnace draft measurements, daily average sludge moisture content, and daily average sludge volatiles content. These data were used with the CEM data to evaluate and compare combustion conditions during the MM5 test periods.

Scrubber system process data obtained include scrubber water flow rates, cyclone, venturi and subcooler section pressure drops, and scrubber system outlet temperature. These data were taken to characterize the consistency of the scrubber system operation during the three MM5 test periods.

4.3 LABORATORY ANALYSES

Laboratory analyses performed on samples from Site SSI-B included dioxin/furan analyses and dioxin/furan precursor analyses. Samples analyzed for dioxin/furan are discussed in Section 4.3.1 and samples analyzed for dioxin/furan precursors are discussed in Section 4.3.2.

4.3.1 Dioxin/Furan Analyses

All dioxin/furan analyses for Site SSI-B samples were performed by EMSL-RTP and ECL-Bay St. Louis laboratories, two of three EPA laboratories collectively referred to as Troika.

Dioxin/furan analyses were performed by gas chromatography/mass spectrometry. Specific isomers identified included 2378-TCDD and 2378-TCDF. Other dioxin/furan compounds were quantitated in groups according to the number of chlorine atoms per molecule. The tetra- through octa-chlorinated homologues were quantified.

Field samples requiring dioxin/furan analysis were prioritized based on their relative importance to the Tier 4 program. The priority levels, in order of decreasing importance, were designated Priority 1, Priority 2, and Priority 3.

Priority 1 samples were sent to Troika with instructions to perform immediate extraction and analysis. These included the MM5 train components and MM5 field blanks for the scrubber exhaust stack, the MM5 lab proof blank, the bottom ash samples and the scrubber blowdown solids/filtrate samples.

Priority 2 samples were sent to Troika to be analyzed for dioxin/furan pending the results of the Priority 1 analyses. The only Priority 2 samples were the sludge feed samples, which were characterized for precursor content only.

The composite soil sample (Priority 3) was transferred to Tier 7 of the National Dioxin Study for potential dioxin/furan analysis.

4.3.2 Dioxin/Furan Precursor Analyses

Dioxin/furan precursor analyses of sludge feed samples were performed by Radian using gas chromatography/mass spectrometry. The specific dioxin/furan precursors being analyzed for included chlorophenols, chlorobenzenes, and PCB's. Composite feed samples were also analyzed for total chlorine by Parr bomb combustion followed by ion chromatography.

5.0 TEST RESULTS

The results of the Tier 4 dioxin/furan emissions test of incinerator SSI-B are presented in this section. The individual test runs are designated as 1, 3, and 5. Process data obtained during the test runs are presented in Section 5.1, and continuous monitoring results for O_2, CO, CO_2, NO_x, and THC are presented in Section 5.2. The flue gas dioxin/furan emissions data are contained in Section 5.3. Sludge feed dioxin/furan precursor data are presented in Section 5.4 and the results of dioxin/furan analyses of bottom ash and scrubber blowdown samples are contained in Section 5.5.

5.1 PROCESS DATA

Process data were obtained to document incinerator and scrubber system operation during the testing. The incinerator data are summarized in Section 5.1.1 and the scrubber system data are summarized in Section 5.1.2. Plant personnel indicated that incinerator and scrubber operation was fairly typical during the test runs.

5.1.1 Incinerator Operating Data

Data summarizing the operation of multiple hearth sewage sludge Incinerator SSI-B during the three MM5 test runs are shown in Table 5-1. Conditions during these test runs were similar except that there was a higher sludge feed rate and a higher percent solids in the sludge during Run 3 as compared to Runs 1 and 5. The amount of dry sludge being fed to the incinerator during Run 3 was 50 percent greater than that fed during Runs 1 and 5.

Oxygen concentration data presented in Table 5-1 are based on analysis of integrated bag samples collected at the air pollution control system exhaust stack. Comparison of the oxygen concentrations for the three test runs shows similar values for Runs 3 and 5. The higher oxygen value for Run 1 compared with Runs 3 and 5 suggests that there was a slightly greater amount of excess combustion air in the incinerator during this test. Oxygen data collected using a continuous monitor at the incinerator outlet indicate this

TABLE 5-1. MEAN INCINERATOR OPERATING PARAMETERS DURING DIOXIN TESTS AT SITE SSI-B.

Parameter	Run 1	Run 3	Run 5	Average
Wet Sludge Feed Rate [Mg/hr (tph)]	6.6 (7.3)	8.0 (8.8)	6.3 (6.9)	6.9 (7.6)
Dry Sludge Feed Rate [Mg/hr (tph)]	2.3 (2.5)	3.4 (3.7)	2.1 (2.3)	2.5 (2.8)
Percent Solids of Wet Sludge (wt %)	33.9	41.7	32.9	36.2
Percent Volatiles of Dry Sludge (wt %)	74.2	74.8	75.1	74.7
Percent O_2 in stack gas[a] (vol. %)	17.9	15.6	15.9	16.5

[a] Oxygen concentration at system exhaust stack based on integrated bag sample analysis using gas chromatography/thermal conductivity detector.

same result, but are less conclusive due to a leak in the CEM sampling system during Run 5. The CEM data are discussed in Section 5.2.

Mean temperatures for each of the incinerator hearths during the MM5 runs are shown in Table 5-2. The temperature profiles for Runs 1 and 5 are very similar. During Run 3 the temperatures for the hearths above Hearth 3 were higher than during Runs 1 and 5, and the temperatures for the hearths below Hearth 3 were lower than during Runs 1 and 5. The observed difference in the temperature profile for Run 3 is a result of both the higher sludge feed rate and the higher solids content for Run 3.

Figures 5-1, 5-2, and 5-3 show the continuous strip chart recordings of the hearth temperatures during the MM5 test runs. As shown in these figures, the temperature on the primary combustion hearth (Hearth 3) was maintained constant during all three tests.

5.1.2 Emission Control Equipment Data

Control equipment operating data collected during the MM5 test runs are summarized in Table 5-3. The data presented in Table 5-3 show average values for various control system parameters based on hourly readings taken during each test run. Comparison of data for the three runs shows no significant differences in operating conditions, with the exception of higher pressure drops and greater steam production during Run 3. The higher pressure drops and greater steam production for Run 3 results from the higher sludge feed rate (Table 5-1).

5.2 CONTINUOUS MONITORING DATA

Mean values and 95 percent confidence intervals for combustion gas concentrations monitored continuously at the incinerator outlet breeching are presented in Tables 5-4 and 5-5. Concentrations of CO, CO_2, NO_x and THC presented in Table 5-5 were corrected or normalized to 3 percent oxygen by volume. Data in Table 5-4 are given at actual stack O_2 levels. The O_2, CO, CO_2, and NO_x values were measured on a dry basis. The sample for THC analysis was pulled through a sample line separate from that used for the other gases and was analyzed on a wet basis.

The O_2 value for Run 5 was invalidated due to an apparent leak in the sample acquisition system. Since the CO, CO_2, and NO_x values presented in

TABLE 5-2. MEAN HEARTH TEMPERATURES DURING DIOXIN EMISSIONS TESTING AT SITE SSI-B

Hearth Number[a]	Hearth Temperatures, °F[b]			
	Run 1	Run 3	Run 5	Average
0	1063	1245	1148	1152
1	1143	1180	1120	1148
2	1417	1508	1420	1448
3	1600	1603	1585	1596
4	1180	873	1105	1053
5	883	428	790	700
6	180	140	200	173
7	100	110	140	117
8	95	100	110	102

[a] Hearths are designated according to plant nomenclature. Hearth No. 0 is the top hearth, Hearth No. 8 is the bottom. Other hearths are numbered sequentially from top to bottom.

[b] Note: °C = (°F - 32)/1.8

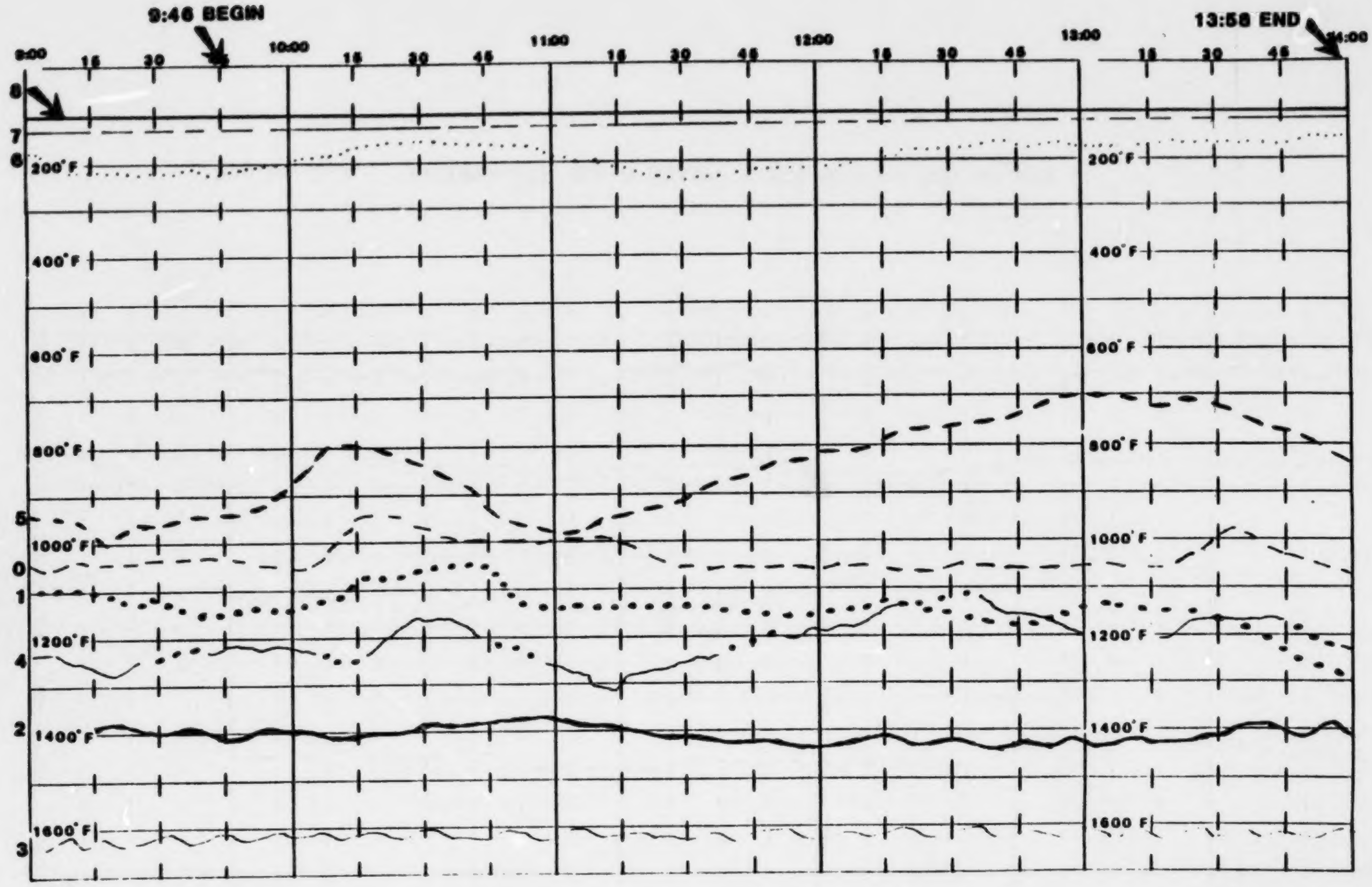


Figure 5-1. INCINERATOR SSI-B HEARTH TEMPERATURES DURING RUN 1.

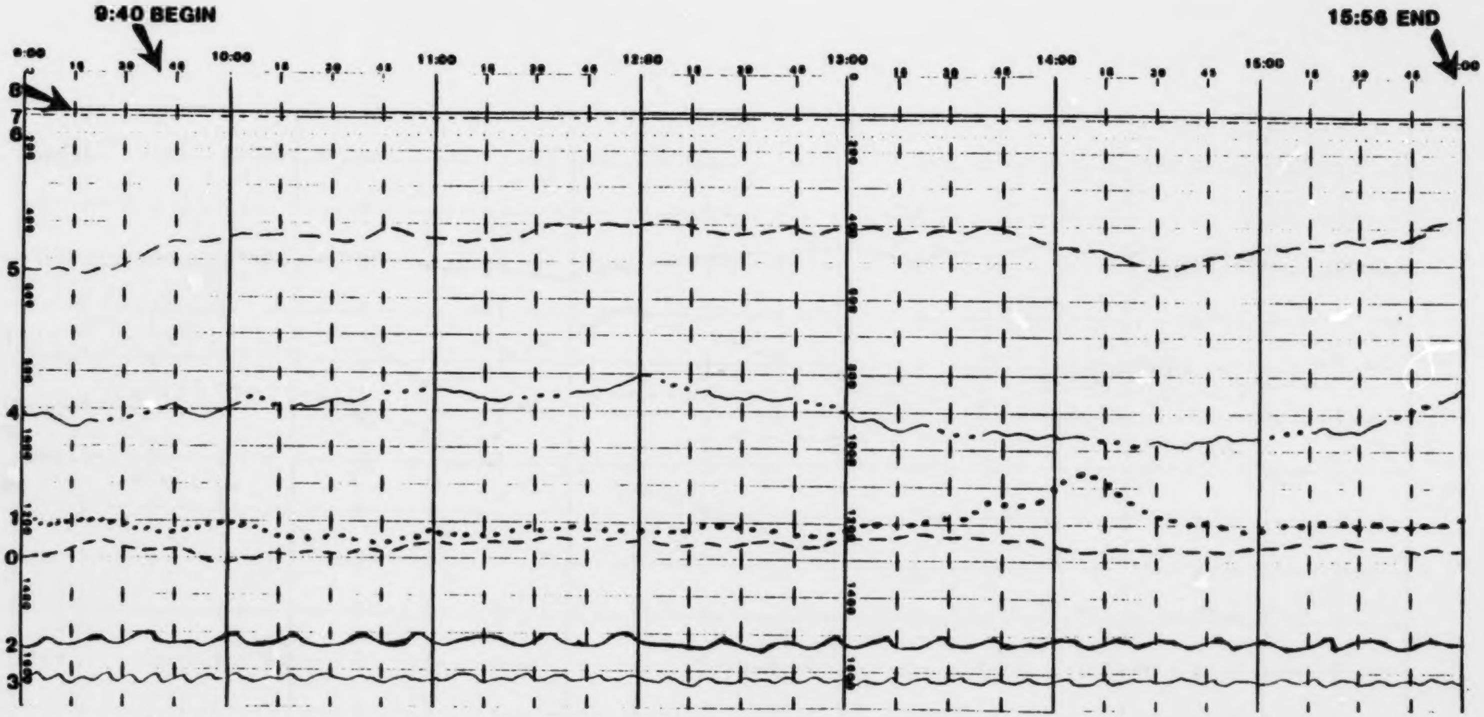


Figure 5-2. INCINERATOR SSI-B HEARTH TEMPERATURES DURING RUN 3

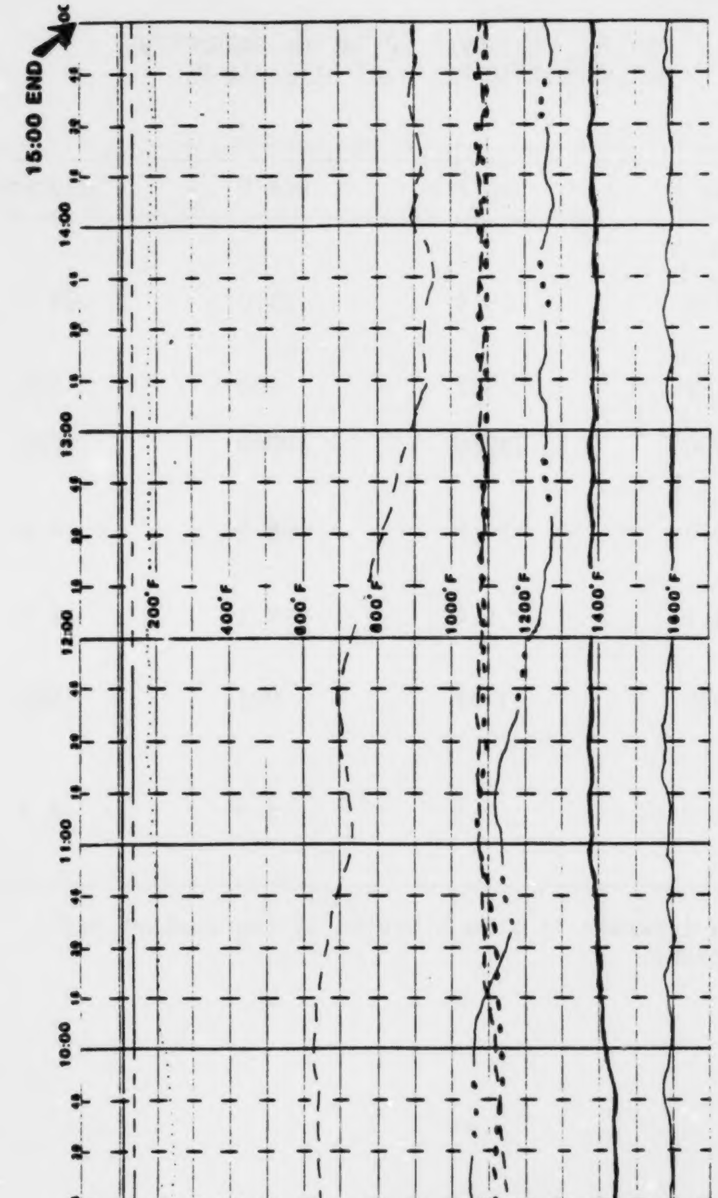


Figure 5-3. INCINERATOR SSI-B HEARTH TEMPERATURES DURING RUN 5

TABLE 5-3. CONTROL EQUIPMENT OPERATING PARAMETERS DURING DIOXIN TESTS AT SITE SSI-B.

Parameter	Run 1	Run 3	Run 5	Average
Venturi ΔP (in H_2O)	24.8	25.4	25.0	25.1
Venturi Water Flowrate (gpm)	190	187	190	189
Steam Production (lb/hr)	9690	13980	10040	11240
Subcooler Outlet Temperature (°F)	69.0	74.9	68.0	70.6
Subcooler ΔP (in H_2O)	4.9	6.0	4.1	5.0
Scrubber Blowdown[a] Water Flowrate (gpm)	936	1185	821	981
Cyclone ΔP (in H_2O)	3.8	7.5	2.9	4.7

[a] The scrubber blowdown flowrate is a combination of the venturi and subcooler water flowrates.

TABLE 5-4. SUMMARY OF CONTINUOUS MONITORING RESULTS FOR SITE SSI-B.

Parameter	Run Number 1 Mean Value (Std. Dev.)	Run Number 3 Mean Value (Std. Dev.)	Run Number 5 Mean Value (Std. Dev.)
Oxygen (Volume %)	14.5 (0.5)	11.7 (0.4)	NA[a]
Carbon Monoxide (ppmv)[b]	2271 (228)	894 (244)	NA
Carbon Dioxide (volume %)	7.3 (1.0)	9.1 (1.0)	NA
Nitrogen oxides (ppmv)[b]	285 (26)	392 (33)	NA
Total hydrocarbons (ppmv)[c]	12.9[d] (6.4)	6.4 (2.2)	48.8 (18.7)

---

[a] Not available. Oxygen value for this run was invalidated due to a leak in the continuous monitor sampling system. Assumed flue gas O_2 to be 13 percent by volume. Values for CO, CO_2, and NO_x corrected to 3% O_2 are presented in Table 5-5.

[b] ppmv = parts per million by volume.

[c] Parts per million by volume as propane.

[d] Based on only 21 consecutive observations. No data collected during second half of test run due to instrument malfunction.

TABLE 5-5. SUMMARY OF CONTINUOUS MONITORING RESULTS FOR INCINERATOR SSI-B (VALUES REFERENCED TO 3% OXYGEN)

Parameter	Run Number 1 Mean Value (Std. Dev.)	Run Number 3 Mean Value (Std. Dev.)	Run Number 5 Mean Value (Std. Dev.)
Oxygen	14.5	11.7	NA[a]
(Volume %)	(0.5)	(0.4)	
Carbon Monoxide	6337	1745	5947
(ppmv)[b]	(627)	(507)	(1096)
Carbon Dioxide	20.3	17.7	18.7
(volume %)[c]	(1.9)	(1.9)	(4.7)
Nitrogen Oxides	804.3	761.3	798.9
(ppmv)[b]	(53.2)	(70.3)	(71.3)
Total hydrocarbons	36.1[e]	12.5	110.6
(ppmv)[d]	(4.5)	(3.3)	(17)

---

[a] Not available. Oxygen value for this run was invalidated due to a leak in the continuous monitor sampling system. Assumed flue gas O_2 to be 13 percent by volume.

[b] ppmv = parts per million by volume corrected to 3% oxygen.

[c] Volume percent corrected to 3% oxygen.

[d] Parts per million by volume as propane, corrected to 3% oxygen.

[e] Based on only 21 consecutive observations. No data collected during second half of test run due to instrument malfunction.

Table 5-5 are corrected to 3 percent O_2, the presence of the sampling system leak does not affect the results for these three parameters. There is no reason to suspect that a leak was also present in the separate sampling system used for THC. To correct the THC value for Run 5 to 3 percent O_2, the actual mean flue gas O_2 concentration at the sample location was assumed to be 13 percent by volume.

Comparison of the mean O_2 values in Table 5-5 for Runs 1 and 3 shows a somewhat lower value for Run 3. The lower O_2 observed for Run 3 is expected to be the result of a higher sludge feed rate during this test run. Data presented for CO in Table 5-5 show similar concentrations for Runs 1 and 5 with a considerably lower concentration for Run 3. Concentrations of CO_2 and NO_x corrected to 3 percent O_2 were similar for all three test runs. Comparison of the mean concentrations in Table 5-5 for THC shows a relatively high THC concentration for Run 5. There is no apparent explanation for the higher THC value for this run.

Instantaneous five-minute values for the continuously monitored gases are shown graphically in Figures 5-4 through 5-8 and are tabulated in Appendix A-2. Values for CO, CO_2, NO_x, and THC are again reported as corrected to 3 percent O_2 by volume. Review of the data presented in Figures 5-4 through 5-7 for O_2, CO, CO_2, and NO_x indicate steady operation of the incinerator throughout each test run. Data presented in Figure 5-8, however, show an increase in THC concentration during Runs 1 and 5 and a slight decrease in concentration during Run 3. In reviewing the THC data presented in Figure 5-8, the difference in the time scale for Run 1 and the concentration scale for Run 5 should be noted. Also, no THC data were collected during the second half of Run 1 because of an instrument malfunction.

5.3 FLUE GAS PARAMETER DATA

Table 5-6 summarizes flue gas temperature, moisture content, and volumetric flow rate data obtained at the incinerator SSI-B outlet stack. These parameters were fairly consistent between the three test runs. The average flue gas temperature and moisture content measured at the scrubber outlet sampling location were 77.1°C (172°F) and 3.72 percent by volume,

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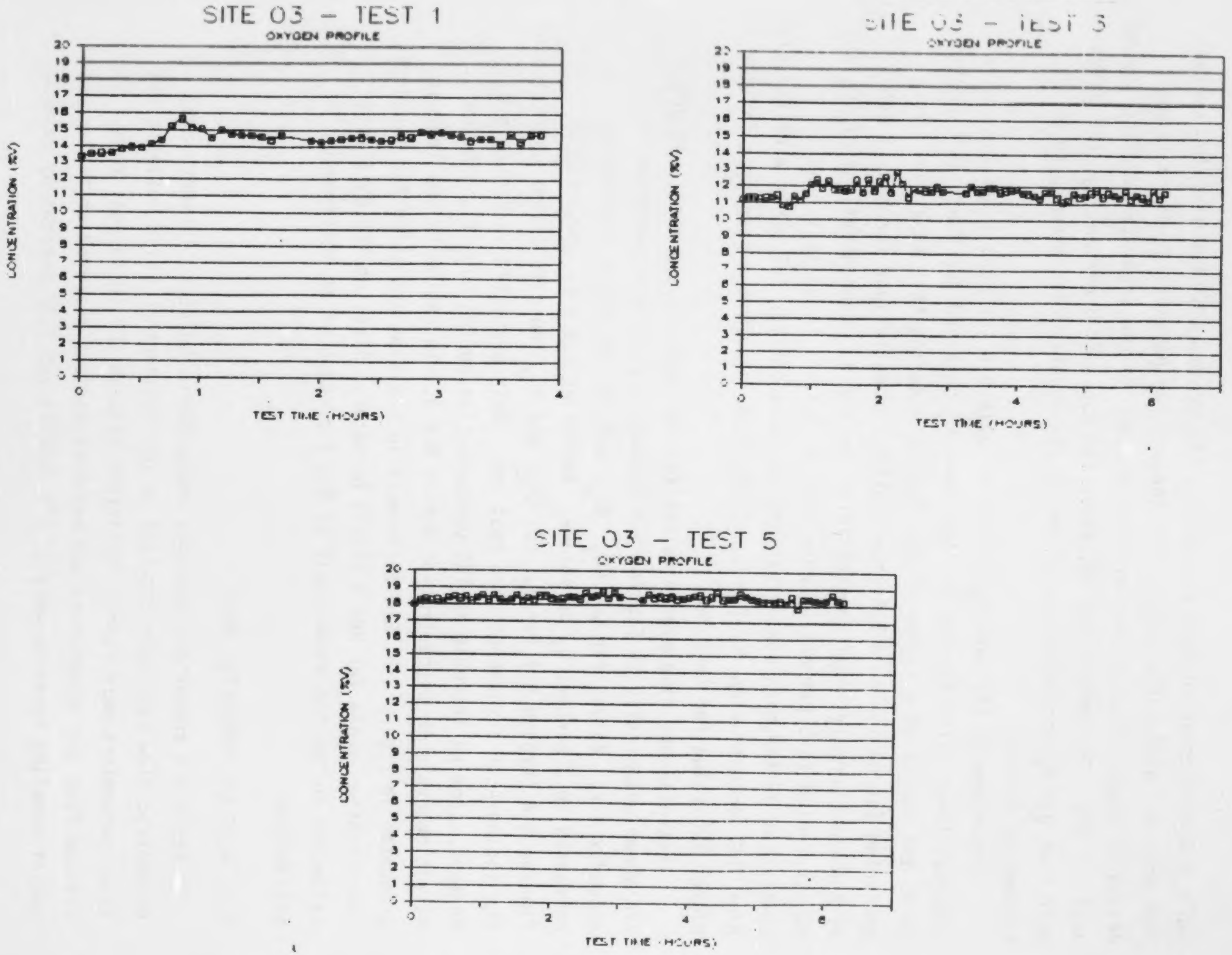

Figure 5-4. OXYGEN CONCENTRATION VS. TIME FOR INCINERATOR SSI-B.

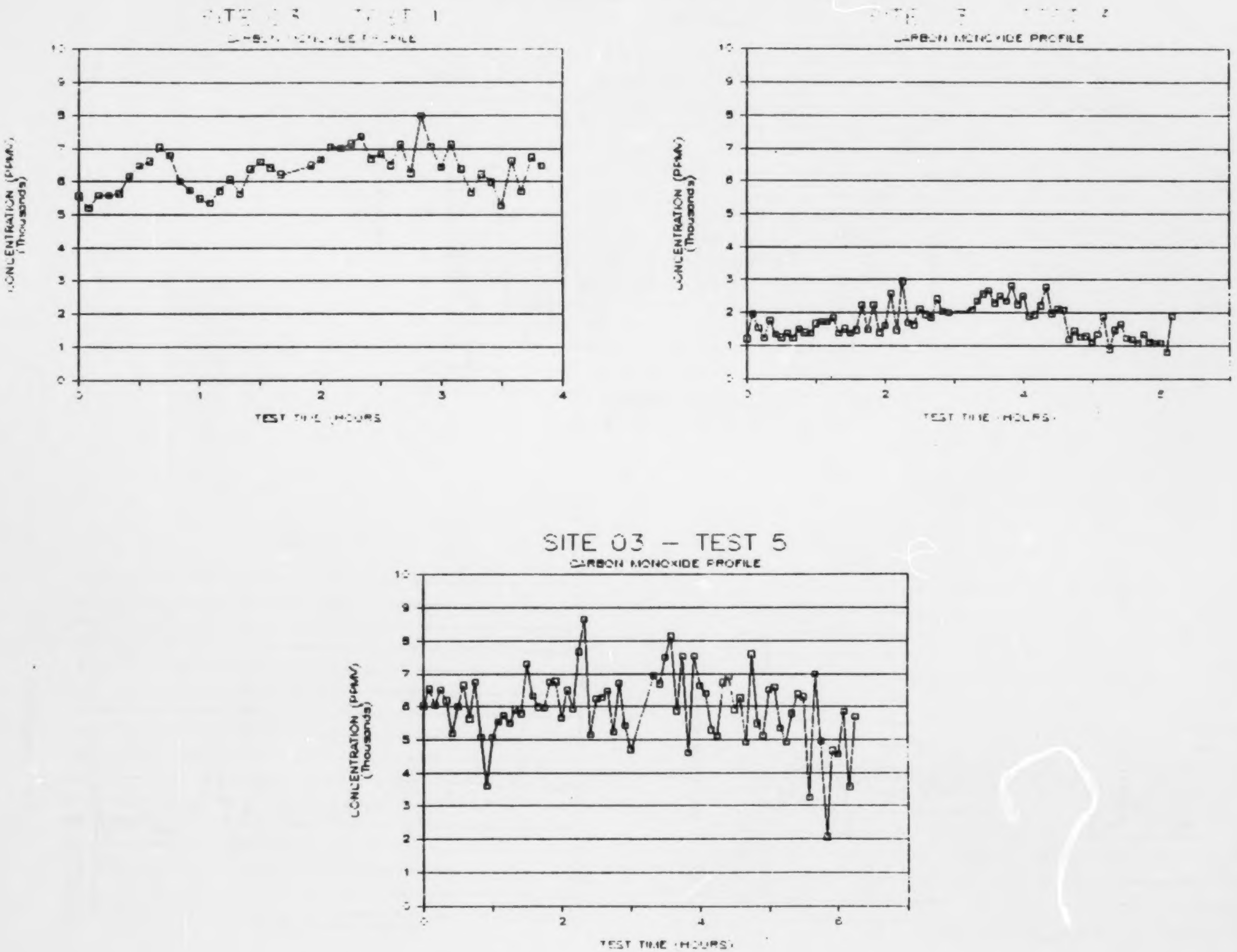

Figure 5-5. CARBON MONOXIDE CONCENTRATION VS. TIME FOR INCINERATOR SSI-B.

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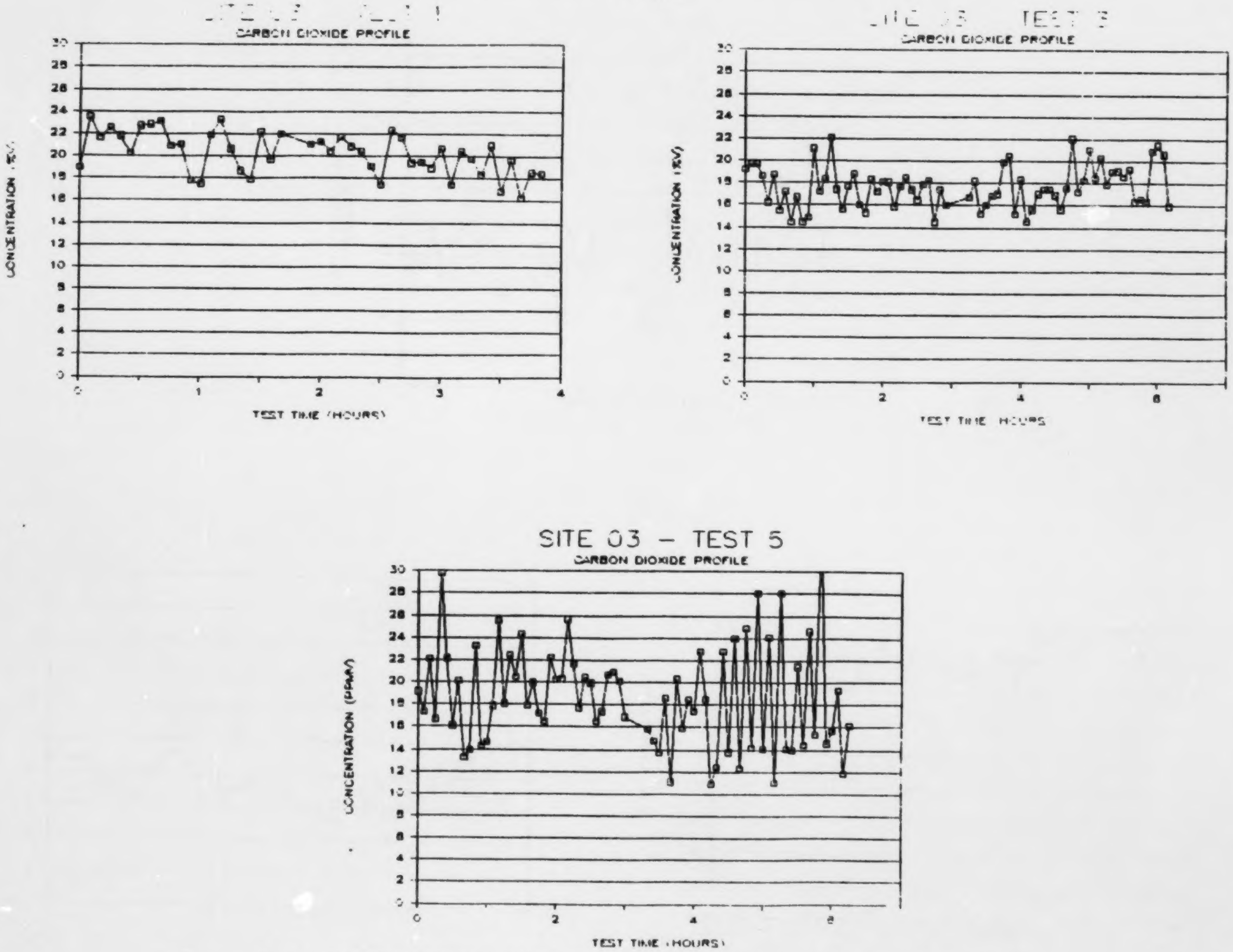


Figure 5-6. CARBON DIOXIDE CONCENTRATION VS. TIME FOR INCINERATOR SSI-B.

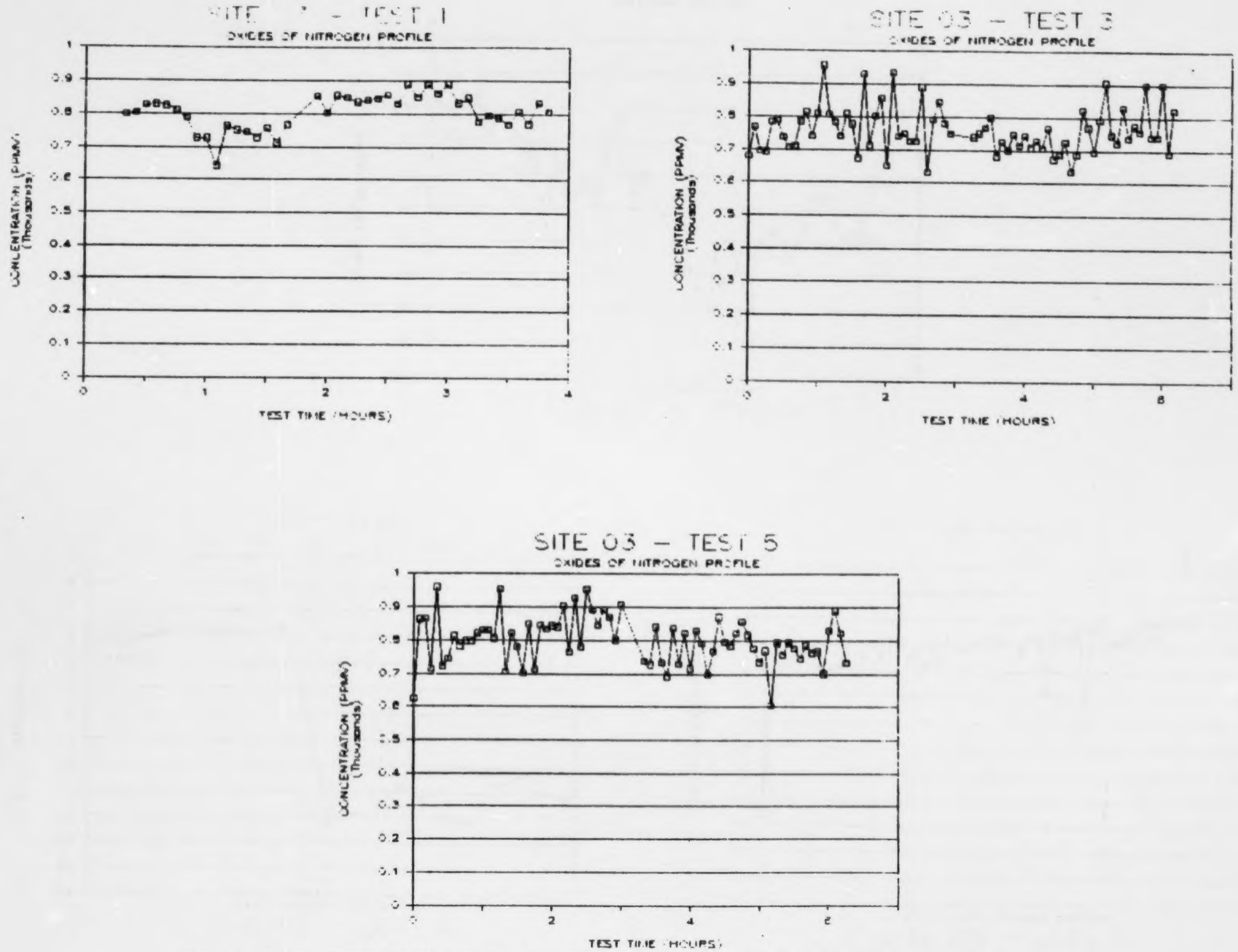


Figure 5-7. NITROGEN OXIDE CONCENTRATION VS. TIME FOR INCINERATOR SSI-B.

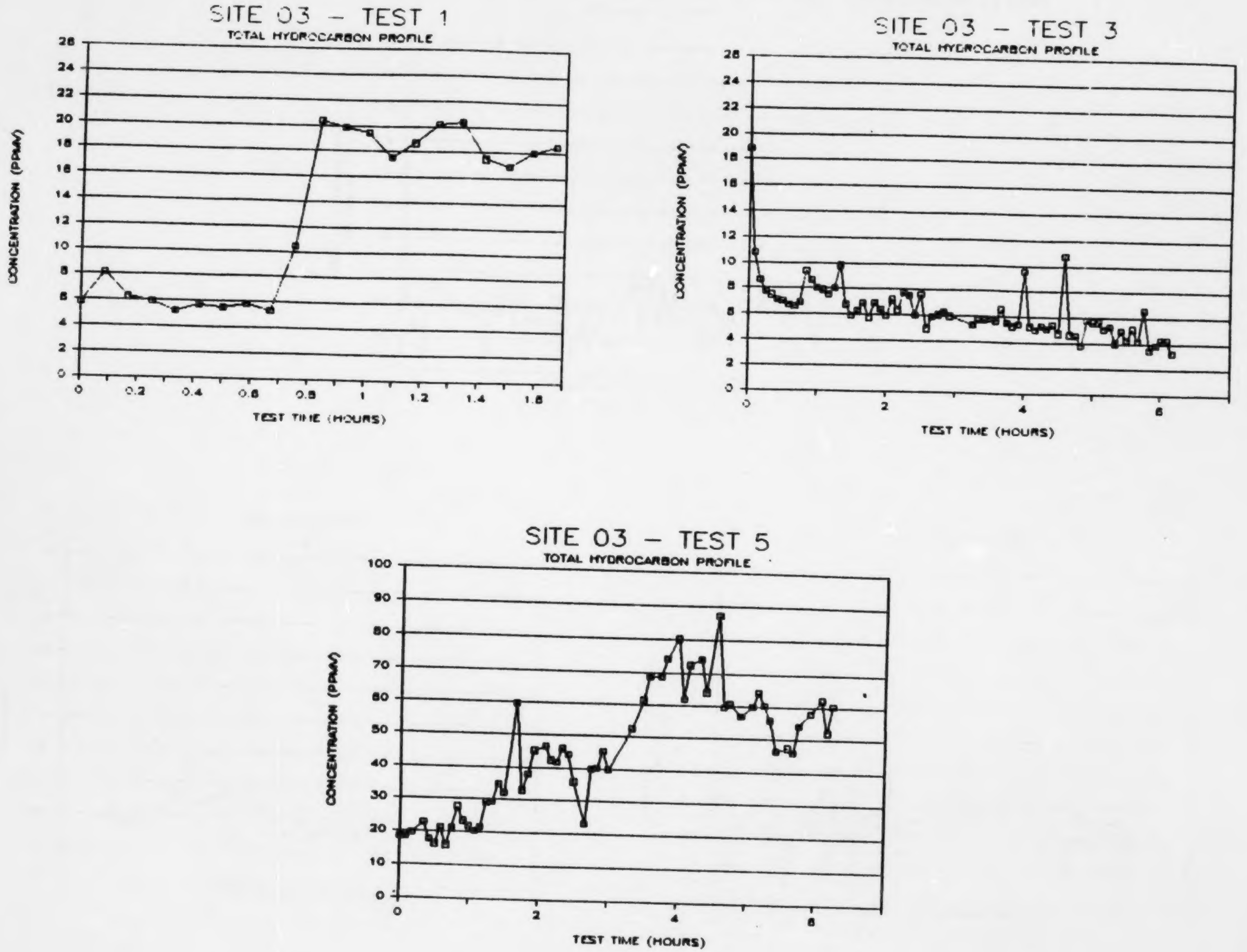


Figure 5-8. TOTAL HYDROCARBON CONCENTRATIONS VS. TIME FOR INCINERATOR SSI-B

TABLE 5-6. FLUE GAS PARAMETERS FOR INCINERATOR SSI-B (AIRSTREAM IN STACK AT SCRUBBER OUTLET)

Flue Gas Parameters	Run 01	Run 03	Run 05	Average
Temperature (^{o}C)	76.4	76.4	78.4	77.1
Moisture (Vol. %)	3.38	4.76	3.01	3.72
Volumetric Flow Rate				
Actual (acmm)	748	792	667	736
Dry Standard (dscmm)	590	622	534	582

respectively. The average exhaust gas flow rate under actual stack temperature and moisture conditions was 736 acmm (25,990 acfm), and the average dry, standard flow rate was 582 dscmm (20,550 dscfm). Standard EPA conditions are 20°C (68°F) and 1 atm.

5.4 DIOXIN/FURAN EMISSIONS DATA

Emission concentrations and emission rate data determined for 2378-TCDD, total PCDD, and total PCDF during Runs 1, 3 and 5 are shown in Table 5-7. Data presented in Table 5-7 include the total dioxin/furan collected in the MM5 sample train (probe, filter, XAD sorbent trap and impingers). Analytical values obtained for each MM5 train were not corrected for blanks. Surrogate recoveries and blank sample train results are discussed in Section 8.0.

As shown in Table 5-7, no detectable quantities of 2378-TCDD were found for any of the three test runs. Emission rates of total PCDD and PCDF averaged 11.6 and 194 ug/hr, respectively.

Isomer- and homologue specific emission concentration data are summarized in Tables 5-8 and 5-9 for the three test runs. Run-specific data tables showing homologue emission concentrations in both ng/dscm and parts-per-trillion units and homologue emission rates in ug/hr units are included in Appendix D. Detectable quantities were found for about half of the target isomers and homologues. Figure 5-9 is a histogram that shows the relative distributions of the homologues that were detected in the stack gas.

Emission factors based on incinerator feed rates (dry basis) are shown in Table 5-10. Average emissions factors for total PCDD's and total PCDF's were 0.05 ug and 0.83 ug per kg of dry solids feed, respectively.

5.5 DIOXIN/FURAN PRECURSOR DATA

Composite sludge feed samples collected for each test run were analyzed for chlorobenzenes, chlorophenols, chlorinated biphenyls, and total chlorine content.

The results of the compound-specific precursor analyses are summarized in Table 5-11. As shown in Table 5-11, the only precursors found in the sludge

TABLE 5-7. SUMMARY OF DIOXIN AND FURAN EMISSION CONCENTRATION AND EMISSION RATE DATA FOR SITE SSI-B (STACK LOCATION)

Run Number	2378 TCDD	Total PCDD	Total PCDF
Emission Rate (ug/hr)			
Run 01	ND[a]	21.8	396
Run 03	ND	6.53	66.2
Run 05	ND	6.44	121
Average	ND	11.6	194
Emissions Concentration at actual O_2, ng/dscm			
Run 01	ND	0.62	11.2
Run 03	ND	0.18	1.77
Run 05	ND	0.20	3.79
Average	ND	0.33	5.59
Emissions Concentration[b] (corrected to 3% O_2), ng/dscm			
Run 01	ND	3.52	64.0
Run 03	ND	0.59	5.94
Run 05	ND	0.68	12.9
Average	ND	1.60	27.9

---

[a] ND = not detected. Detection limits ranged from 0.4 to 8.4 ug/hr and 0.01 to 0.24 ng/dscm, depending on the particular homologues.

[b] Flue gas concentration data corrected to 3% O_2 using the EPA Method 3 data presented in Table 5-1.

TABLE 5-8. SUMMARY OF DIOXIN/FURAN EMISSIONS DATA FOR SITE SSI-B
(At Actual Stack Oxygen Concentration)

Dioxin/Furan Isomer	Isomer Concentration in Flue Gas (ng/dscm)			
	Run 01	Run 03	Run 05	Avg.
DIOXINS				
2378 TCDD	ND(1.15E-02)	ND(6.00E-02)	ND(1.15E-02)	.00E+00
Other TCDD	1.92E-01	ND(6.00E-02)	2.87E-02	7.37E-02
Penta-CDD	ND(1.92E-02)	ND(4.50E-02)	ND(5.75E-02)	.00E+00
Hexa-CDD	ND(1.85E-01)	ND(1.02E-01)	ND(8.62E-03)	.00E+00
Hepta-CDD	1.15E-01	ND(6.75E-02)	ND(4.02E-02)	3.85E-02
Octa-CDD	3.08E-01	1.75E-01	1.72E-01	2.18E-01
Total PCDD	6.15E-01	1.75E-01	2.01E-01	3.31E-01
FURANS				
2378 TCDF	7.31E-01	2.50E-01	4.02E-01	4.61E-01
Other TCDF	7.50E+00	1.52E+00	2.67E+00	3.90E+00
Penta-CDF	2.08E+00	ND(4.50E-02)	7.18E-01	9.32E-01
Hexa-CDF	8.46E-01	ND(5.75E-02)	ND(2.13E-01)	2.82E-01
Hepta-CDF	ND(2.38E-01)	ND(7.25E-02)	ND(2.01E-02)	.00E+00
Octa-CDF	3.85E-02	ND(1.25E-02)	ND(1.72E-02)	1.28E-02
Total PCDF	1.12E+01	1.77E+00	3.79E+00	5.59E+00

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

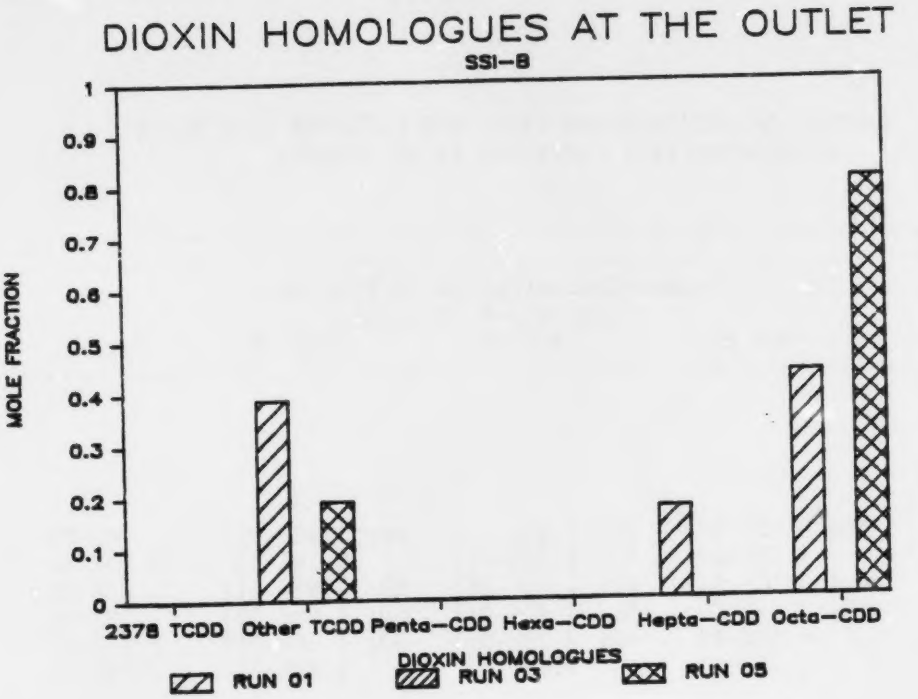
ND = not detected (detection limit in parentheses).
ng = 1.0E-09g
8760 operating hours per year

TABLE 5-9. SUMMARY OF DIOXIN/FURAN EMISSIONS DATA FOR SITE SSI-B
(Concentrations Corrected to 3% Oxygen)

Dioxin/Furan Isomer	Isomer Concentration in Flue Gas (ng/dscm @ 3% oxygen) Run 01	Run 03	Run 05	Avg.
DIOXINS				
2378 TCDD	ND(6.59E-02)	ND(2.01E-01)	ND(3.90E-02)	.00E+00
Other TCDD	1.10E+00	ND(2.01E-01)	9.74E-02	3.99E-01
Penta-CDD	ND(1.10E-01)	ND(1.51E-01)	ND(1.95E-01)	.00E+00
Hexa-CDD	ND(1.05E+00)	ND(3.43E-01)	ND(2.92E-02)	.00E+00
Hepta-CDD	6.59E-01	ND(2.26E-01)	ND(1.36E-01)	2.20E-01
Octa-CDD	1.76E+00	5.86E-01	5.84E-01	9.76E-01
Total PCDD	3.52E+00	5.86E-01	6.82E-01	1.59E+00
FURANS				
2378 TCDF	4.18E+00	8.36E-01	1.36E+00	2.13E+00
Other TCDF	4.29E+01	5.10E+00	9.06E+00	1.90E+01
Penta-CDF	1.19E+01	ND(1.51E-01)	2.44E+00	4.77E+00
Hexa-CDF	4.84E+00	ND(1.92E-01)	ND(7.21E-01)	1.61E+00
Hepta-CDF	ND(1.36E+00)	ND(2.43E-01)	ND(6.82E-02)	.00E+00
Octa-CDF	2.20E-01	ND(4.18E-02)	ND(5.84E-02)	7.33E-02
Total PCDF	6.40E+01	5.94E+00	1.29E+01	2.76E+01

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = not detected (detection limit in parentheses).
ng = 1.0E-09g
8760 operating hours per year



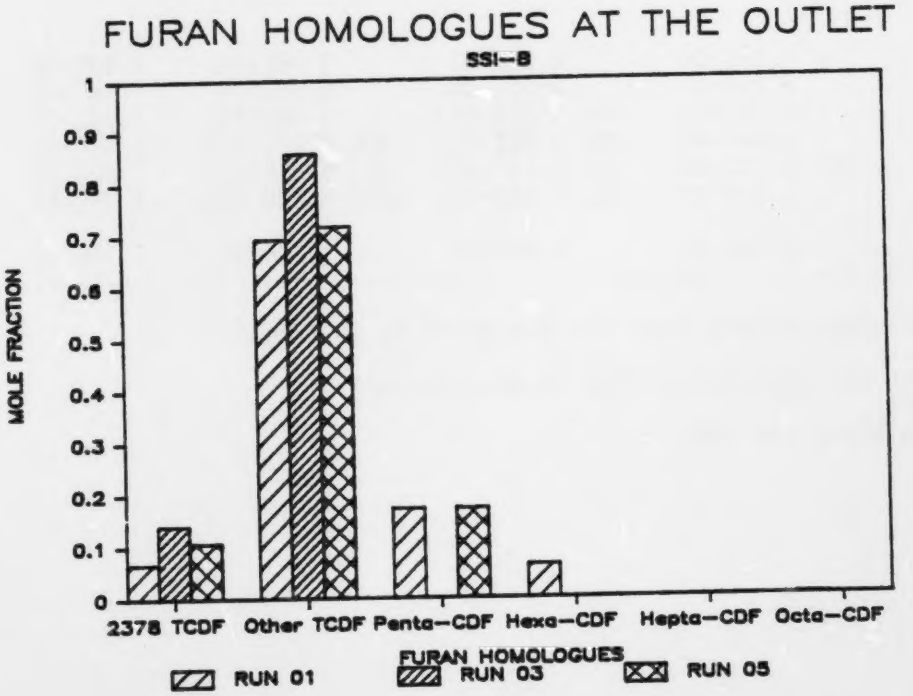


Figure 5-9. Distribution of dioxin and furan homologues in scrubber outlet emissions.

TABLE 5-10. DIOXIN/FURAN EMISSION FACTORS FOR SITE SSI-B

Dioxin/Furan Isomer	Dioxin/Furan Emission Factors (ug/kg)			
	Run 01	Run 02	Run 03	Avg.
DIOXINS				
2378 TCDD	ND(1.77E-04)	ND(6.59E-04)	ND(1.75E-04)	.00E+00
Other TCDD	2.96E-03	ND(6.59E-04)	4.38E-04	1.13E-03
Penta-CDD	ND(2.96E-04)	ND(4.94E-04)	ND(8.77E-04)	.00E+00
Hexa-CDD	ND(2.84E-03)	ND(1.12E-03)	ND(1.31E-04)	.00E+00
Hepta-CDD	1.77E-03	ND(7.41E-04)	ND(6.14E-04)	5.92E-04
Octa-CDD	4.73E-03	1.92E-03	2.63E-03	3.09E-03
Total PCDD	9.47E-03	1.92E-03	3.07E-03	4.82E-03
FURANS				
2378 TCDF	1.12E-02	2.74E-03	6.14E-03	6.71E-03
Other TCDF	1.15E-01	1.67E-02	4.08E-02	5.76E-02
Penta-CDF	3.19E-02	ND(4.94E-04)	1.10E-02	1.43E-02
Hexa-CDF	1.30E-02	ND(6.31E-04)	ND(3.24E-03)	4.34E-03
Hepta-CDF	ND(3.67E-03)	ND(7.96E-04)	ND(3.07E-04)	.00E+00
Octa-CDF	5.92E-04	ND(1.37E-04)	ND(2.63E-04)	1.97E-04
Total PCDF	1.72E-01	1.95E-02	5.79E-02	8.32E-02

ND = not detected (detection limit in parentheses).
ug = 1.0E-06g
8760 operating hours per year

TABLE 5-11. SUMMARY OF PRECURSOR ANALYSES ON SLUDGE FEED SAMPLES

Precursor Compounds	Precursor Concentration (ppm by weight)		
	Run 1	Run 3	Run 5
TOTAL CHLORINATED BENZENES	0.03	0.04	0.02
Dichlorobenzenes	0.03	0.04	0.02
Other chlorobenzenes	ND[a]	ND	ND
TOTAL CHLORINATED BIPHENYLS	ND	ND	ND
TOTAL CHLORINATED PHENOLS	ND	ND	ND

[a] ND = not detected. Detection limit was approximately 0.02 parts per million.

feed was dichlorobenzene, at levels ranging from 0.02 to 0.04 ppm by weight. No chlorinated biphenols or chlorinated phenols were found.

Results for the total chlorine analyses are presented in Table 5-12. The sludge chlorine content was similar for all three test runs and averaged 214 ppm by weight.

5.6 SLUDGE, BOTTOM ASH AND SCRUBBER BLOWDOWN DIOXIN/FURAN DATA

Samples of the sludge feed were taken during the test runs and composited for analysis. The dioxin/furan concentrations in the sludge feed are shown in Table 5-13. With the exception of TCDD, TCDF, and penta-CDF, all other homologues were detected. Hourly samples of incinerator bottom ash and scrubber blowdown water were taken during the test runs and composited for analysis. The dioxin/furan concentrations in the bottom ash are shown in Table 5-14. The only homologues detected were octa-CDD, TCDF, and octa-CDF.

The scrubber water samples were filtered, resulting in two components: filterable scrubber solids, and scrubber filtrate. Approximately 16 liters of scrubber blowdown water was filtered each run. Results of the dioxin/furan analysis of the scrubber filtrate are shown in Table 5-15. Only TCDF and penta-CDF homologues were detected at concentrations less than 2 ng per 16 liters of filtrate. Results of the dioxin/furan analysis of the filterable scrubber solids are shown in Table 5-16. All of the homologues were detected in these samples.

5.7 SOIL DIOXIN/FURAN DATA

The soil sample was turned over to Tier 7 for analysis. Because of the low stack concentrations of dioxins/furans, it was decided that analysis of the soil sample was not warranted.

TABLE 5-12. SUMMARY OF TOTAL CHLORIDE DATA IN SLUDGE FEED SAMPLES

Test Run	Total Chloride (ppm)[a]
01	208
02	201
05	232
Average	214

[a] ppm = parts per million, weight basis (ug/g), blank corrected.

TABLE 5-13. DIOXIN/FURAN CONCENTRATIONS IN THE SLUDGE FEED AT SITE SSI-B[a]

Dioxin/Furan Homologue	Dioxin/Furan Concentration (ppb)
Dioxins	
2378-TCDD	b
Other TCDD	ND (0.03)
Penta-CDD	0.05
Hexa CDD	1.4
Hepta CDD	0.9
Octa CDD	2.8
Total PCDD	5.15
Furans	
2378-TCDF	b
Other TCDF	ND (0.05)
Penta-CDF	ND (0.05)
Hexa CDF	0.07
Hepta CDF	0.2
Octa CDF	0.1
Total PCDF	0.37

ND = Not detected at specified minimum limit of detection.

[a] Composite sludge feed sample.

[b] ND for 2378 isomers is estimated to be less than half of the ND shown for TCDD's and TCDF's.

TABLE 5-14. DIOXIN/FURAN CONCENTRATIONS IN THE BOTTOM ASH AT SITE SSI-B

Dioxin/Furan Homologue	Dioxin/Furan Concentration (ppb)		
	Run 01	Run 03	Run 05
Dioxins			
2378-TCDD	ND	ND	ND
Other TCDD	ND	ND	ND
Penta CDD	ND	ND	ND
Hexa CDD	ND	ND	ND
Hepta CDD	ND	ND	ND
Octa CDD	0.01	0.01	0.01
Total PCDD	0.01	0.01	0.01
Furans			
2378-TCDF	ND	ND	ND
Other TCDF	ND	0.04	0.08
Penta CDF	ND	ND	ND
Hexa CDF	ND	ND	ND
Hepta CDF	ND	0.007	ND
Octa CDF	ND	ND	ND
Total PCDF	ND	0.047	0.08

ND = not detected. Detection limits ranged from 0.001 to 0.01 ppb. The average detection limit was 0.01 ppb.

TABLE 5-15. DIOXIN/FURAN CONCENTRATIONS IN SCRUBBER FILTRATE AT SITE SSI-B

Dioxin/Furan Homologue	Dioxin/Furan Concentration (ng)[a]	
	Run 03	Run 05
Dioxins		
2378-TCDD	ND	ND
Other TCDD	ND	ND
Penta-CDD	ND	ND
Hexa-CDD	ND	ND
Hepta-CDD	ND	ND
Octa-CDD	ND	ND
Total PCDD	ND	ND
Furans		
2378-TCDF	ND	ND
Other TCDF	0.2	1.7
Penta-CDF	ND	0.7
Hexa-CDF	ND	ND
Hepta-CDF	ND	ND
Octa-CDF	ND	ND
Total PCDF	0.2	2.4

[a] Approximately 16 liters of scrubber blowdown water was filtered each run. Results of the analysis for Run 01 were unavailable.

ND = Not detected. The detection limits for dioxins ranged from 0.01 to 0.53 ng/sample. For furans, the detection limits ranged from 0.1 to 0.2 ng/sample.

TABLE 5-16. DIOXIN/FURAN CONCENTRATIONS IN THE FILTERABLE SCRUBBER SOLIDS AT SITE SSI-B

Dioxin/Furan Homologue	Dioxin/Furan Concentration (ppb) Run 03	 Run 05
Dioxins		
2378-TCDD	0.002	ND (0.005)
Other TCDD	0.05	0.11
Penta-CDD	0.03	0.02
Hexa-CDD	0.07	0.08
Hepta-CDD	0.14	0.08
Octa-CDD	0.15	0.11
Total PCDD	0.44	0.40
Furans		
2378-TCDF	0.09	0.54
Other TCDF	0.51	2.6
Penta-CDF	0.19	1.2
Hexa-CDF	0.16	0.8
Hepta-CDF	0.12	0.13
Octa-CDF	0.03	0.02
Total PCDF	1.1	5.3

ND = Not detected at specified minimum limit of detection.

6.0 SAMPLING LOCATIONS AND PROCEDURES

Samples were collected from six different locations around the Site SSI-B incinerator. The specific sampling locations are shown in Figure 6-1. Two of the locations were for gaseous sampling, one was for liquid/slurry sampling, and three were for solids sampling. The source sampling and analysis matrix in Table 6-1 shows the sample location, the parameter measured, the sampling method, and the analysis method.

Details on the sampling locations and methods are discussed in Sections 6.1 through 6.3. Analytical procedures for continuous monitoring samples and molecular weight determinations are included in Section 6.1. All other analytical procedures are discussed in Section 7.

6.1 GASEOUS SAMPLES

Two types of gaseous samples were taken during the testing: Modified Method 5 (MM5) and continuous monitoring (CEM). The sampling locations and methods are further discussed below.

6.1.1 Gaseous Sampling Locations

Outlet Exhaust Stack Location

The system outlet exhaust stack location is shown as Point E in Figure 6-1. This location was used for dioxin sampling using MM5 and for gas velocity, molecular weight, and moisture determinations using EPA Methods 1 through 4.

Exhaust gases from the incinerator and associated control equipment were vented through a jacketed 0.8m (2.5 ft) diameter stack. Dimensions of the outlet exhaust stack are shown in Figure 6-2. The outer stack had a 0.9m (3 ft) diameter and four 10cm (4 inch) sampling ports that extended through the annulus between the two stacks. A fan located approximately 3.7m (12 ft) below the sampling ports forced ambient building air through the annular space. None of this air mixed with the incinerator exhaust gases prior to the sampling ports. The nearest downstream flow disturbance was the stack discharge, located 1.5m (5 ft) or 2.0 duct diameters downstream of the ports. A total of 24 traverse points were used for velocity determination at this location.

TABLE 6-1. SOURCE SAMPLING AND ANALYSIS MATRIX - SITE SSI-B

Sample Location	Sample Type or Parameter	Sampling Method	Analysis Method	Number of Samples or Frequency
Outlet exhaust stack (point E on Figure 6-1)	Dioxin and furan	Modified EPA Method 5 (MM5)	Gas chromatograph/mass spectrometer	Five test runs[a]; one per test day.
	Volumetric flow	EPA Method 2	NA[b]	Once per MM5 test run.
	Molecular weight	EPA Method 3	Gas chromatograph/thermal conductivity detector	Two integrated bag samples per MM5 test run.
	Moisture	EPA Method 4	Gravimetric balance	Once per MM5 test run.
Incinerator outlet location (point B on Figure 6-1)	CO/CO_2	In-stack filter probe and heat-traced teflon line	Nondispersive infrared analysis	Continuously during MM5 test runs.
	O_2	Same as CO/CO_2	Paramagnetic analzer	Continuously during MM5 test runs.
	NO_x	Same as CO/CO_2	Chemiluminescent analyzer	Continuously during MM5 test runs.
	THC	Same as CO/CO_2	Flame ionization analyzer[c]	Continuously during MM5 test runs.
Sludge feed	Dioxin precursors	Grab samples	Gas chromatograph/mass spectrometer	Duplicate composite samples for each test run.
Bottom ash	Dioxin and furan	Grab samples	Gas chromatograph/mass spectrometer	Duplicate composite samples for each test run.
Scrubber blowdown	Scrubber blowdown solids for dioxin and furan	Pressure filtration	Gas chromatograph/mass spectrometer	One composite sample per MM5 test run.
	Scrubber blowdown filtrate for dioxin and furan	Pressure filtration	Gas chromatograph/mass spectrometer	One composite sample per MM5 test run.
	Scrubber blowdown for weight percent solids	Vacuum filtration	Gravimetric balance	One composite sample per MM5 test run.
Soils	Dioxin and furan	Grab samples	Gas chromatograph/mass spectrometer	One composite of 10 samples.

[a] The second test run was invalidated because the filter popped up from the teflon frit sometime during the sampling run. The fourth test run was aborted due to large fluctuations in sludge composition and moisture content that led to extended non-representative operation of the incinerator.

[b] NA = not applicable.

[c] The flame ionization analyzer was calibrated using propane standards.

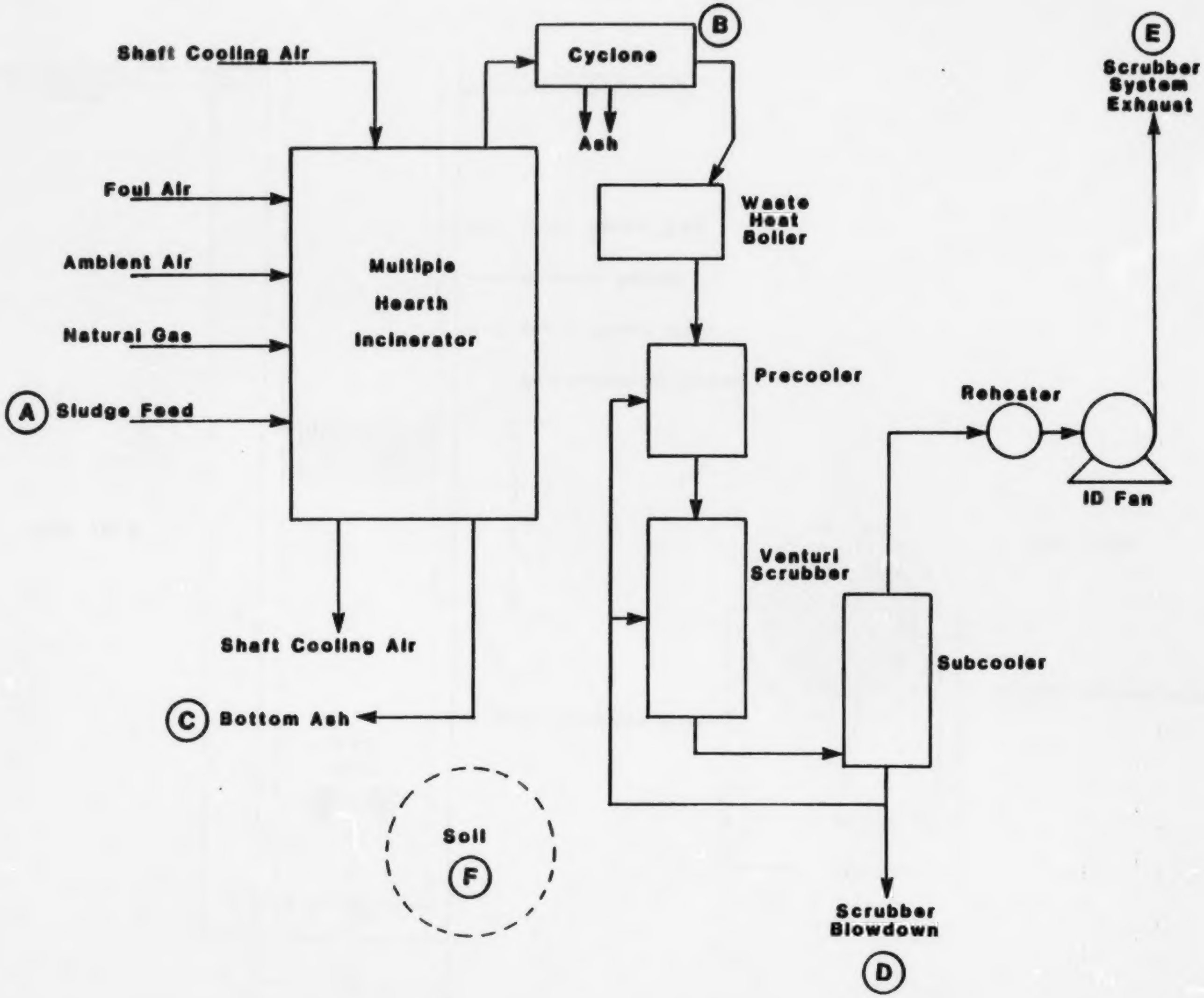

Shaft Cooling Air
Foul Air
Ambient Air
Natural Gas
A
Sludge Feed
Multiple
Hearth
Incinerator
Cyclone
B
Ash
Waste
Heat
Boiler
Precooler
Venturi
Scrubber
Subcooler
Reheater
ID Fan
E
Scrubber
System
Exhaust
Shaft Cooling Air
C
Bottom Ash
Soil
F
Scrubber
Blowdown
D

Figure 6-1. SAMPLE POINT DIAGRAM FOR SITE SSI-B

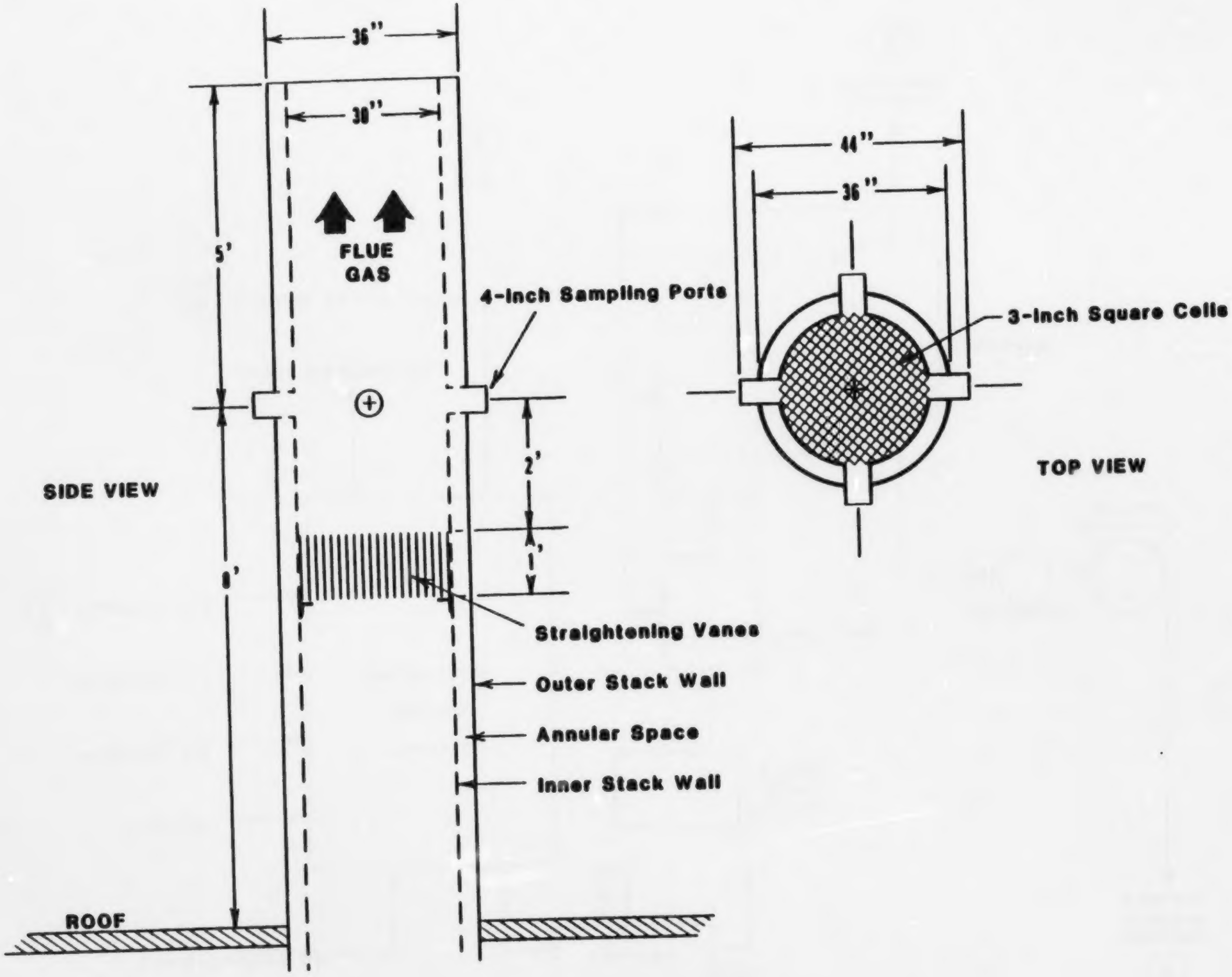

36"
30"
5'
8'
FLUE GAS
4-Inch Sampling Ports
2'
1'
SIDE VIEW
Straightening Vanes
Outer Stack Wall
Annular Space
Inner Stack Wall
ROOF
44"
36"
3-Inch Square Cells
TOP VIEW

Figure 6-2. DIAGRAM OF OUTLET STACK SAMPLING LOCATIONS

Due to the presence of cyclonic flow, straightening vanes had to be installed in the inner stack to allow for valid MM5 testing. The nearest upstream flow disturbance prior to the straightening vanes was the ID fan, which was located 7.9m (26 ft) or 10.4 duct diameters upstream of the ports. There is no apparent reason for the observed cyclonic flow.

The straightening vanes, which consisted essentially of a 0.3m (1 ft) long honeycomb of 8cm (3 inch) square cells, was slipped into the stack so that the top of the vanes was 0.6m (2 ft) below the ports. The straightening vanes removed the cyclonic flow although the gas velocity remained low in the center of the stack and high near the stack walls.

Incinerator Outlet Sample Location

The incinerator outlet location is shown as Point B on Figure 6-1. This location was used for obtaining a gas sample for continuous monitoring of O_2, CO_2, CO, NO_x, and THC. Sample acquisition was accomplished using an in-stack filter probe and heat-traced Teflon sample line leading from the incinerator outlet location to the continuous monitoring equipment.

6.1.2 Gaseous Sampling Procedures

Gas sampling procedures used during this program are discussed in detail in the Tier 4 Quality Assurance Project Plan (QAPP).[1] A brief description of each method and any necessary deviations from the procedures outlined in the QAPP are provided in the following sections.

Modified Method 5 (MM5)

Gas sampling for dioxins was conducted according to the latest draft (October 1984) of the American Society of Mechanical Engineers (ASME) chlorinated organic compound sampling protocol. This sampling method is a modified version of EPA Method 5 that includes a solid sorbent module (XAD-2) for trapping vapor phase organics. The MM5 sampling train was used to collect samples at the system outlet exhaust stack. Following sample recovery, the various parts of the sample (filter, solvent rinses, sorbent trap, etc.) were sent to EPA's Troika laboratories to quantify the 2378-TCDD and tetra- through octa-dioxin/furan homologues present in the samples.

A total of five MM5 test runs were conducted at the outlet exhaust stack location with one test run being conducted per test day. The second test run was invalidated because the filter popped up from the Teflon frit sometime during the test run. While the sample train still met all leak check requirements, a decision was made to discard the sample because some of the particulate matter may have bypassed the filter and entered the resin trap. The fourth test run was aborted after completion of 13 of 24 traverse points. The run was aborted due to large fluctuations in sludge composition and moisture content that led to extended periods of non-representative incinerator operation.

Based on the QAPP, the desired isokinetic sampling rate for the MM5 train is 0.85 m^3/hr (0.5 scfm) to provide a sample volume of 3.4 m^3 (120 scf) over a 4 hour sampling period. Due to the stack gas velocity at this site and the available nozzle sizes, isokinetic sampling had to be conducted at a sampling rate of approximately 0.68 m^3/hr (0.40 scfm). During the first run, each of 24 traverse points was sampled for 10 minutes, providing a total sample volume of 2.7 m^3 (95 scf). The sampling time at each point was increased to 15 minutes for the remaining test runs, providing total sample volumes of approximately 4.0 m^3 (140 scf).

A schematic diagram of the MM5 sampling train is shown in Figure 6-3. Flue gas is pulled from the stack through a nozzle and heated gas probe. Particulate matter is removed from the gas stream by means of a fiberglass filter housed in a Teflon-sealed glass filter holder maintained at $120 \pm 14^{\circ}$C ($248 \pm 25^{\circ}$F). The gas passes through a sorbent trap similar to that illustrated in Figure 6-4 for removal of organic constituents. The trap consists of separate sections for (1) cooling the gas stream, and (2) adsorbing the organic compounds on Amberlite XAD-2^R resin (XAD). A chilled impinger train is used to remove water from the flue gas, and a dry gas meter is used to measure the sample gas flow.

Volumetric Gas Flow Rate Determination

The volumetric gas flow rate was determined during this program using procedures described in EPA Method 2. Based on this method, the volumetric gas flow rate is determined by measuring the cross-sectional area of the duct and the average velocity of the flue gas. The average flue gas velocity is calculated from the average gas velocity pressure (P) across the S-type pitot, the average flue gas temperature, wet molecular weight, and the absolute static pressure.

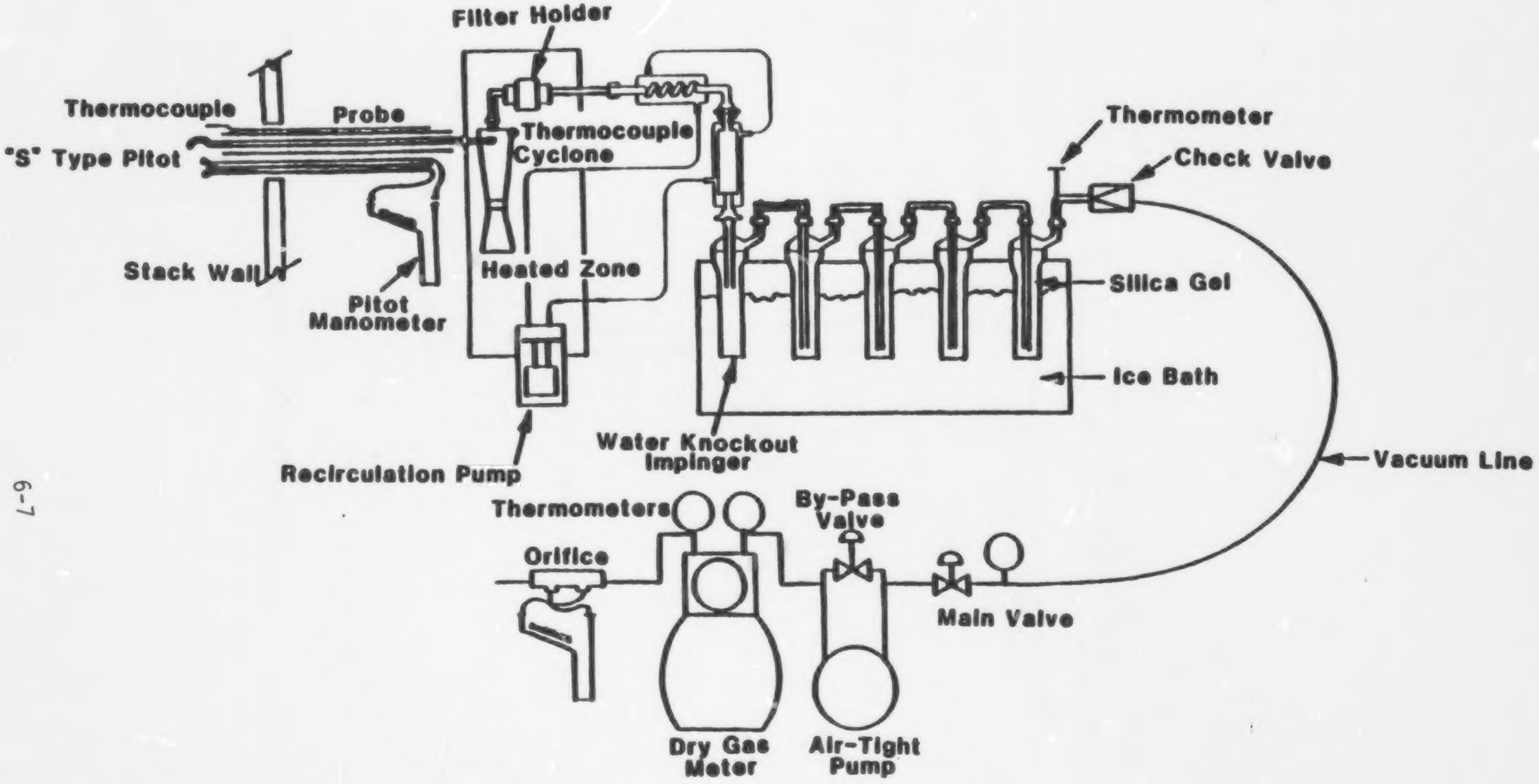

Filter Holder
Thermocouple
Probe
Thermocouple
Cyclone
"S" Type Pitot
Thermometer
Check Valve
Stack Wall
Pitot
Manometer
Heated Zone
Silica Gel
Ice Bath
Water Knockout
Impinger
Recirculation Pump
Vacuum Line
Thermometers
By-Pass
Valve
Orifice
Main Valve
Dry Gas
Meter
Air-Tight
Pump

Figure 6-3. MODIFIED METHOD 5 TRAIN.

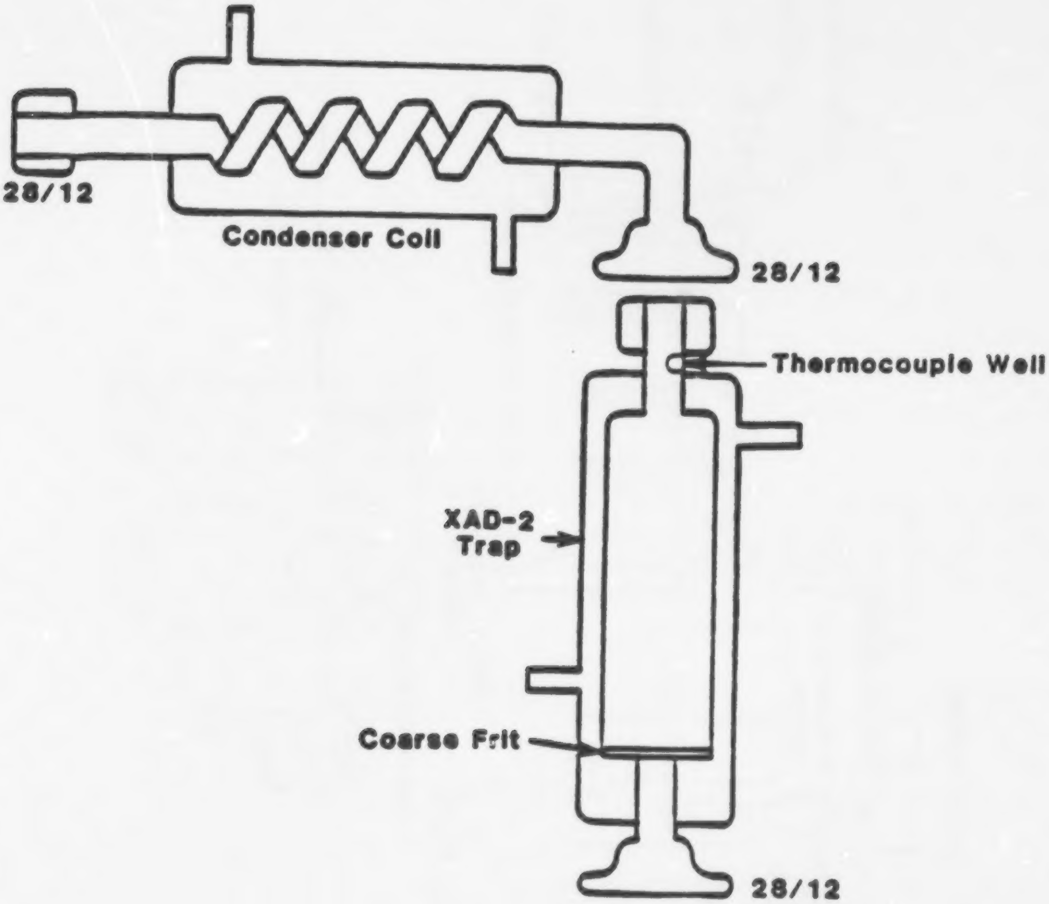

28/12
Condenser Coil
28/12
Thermocouple Well
XAD-2 Trap
Coarse Frit
28/12

Figure 6-4. ADSORBENT SAMPLING SYSTEM

Flue Gas Moisture Determination

The moisture content of the flue gas was determined using the methodology described in EPA Method 4. Based on this method, a known volume of particulate-free gas is pulled through a chilled impinger train. The quantity of condensed water is determined gravimetrically and then related to the volume of gas sample to determine the moisture content.

Flue Gas Molecular Weight Determination

During testing, the integrated sampling technique described in EPA Method 3 was used to obtain an integrated flue gas sample for fixed gas (O_2, CO_2, CO, N_2) analysis. A small diaphragm pump and a stainless steel probe were used to extract a single point flue gas sample which was collected in a Tedlar^R bag. Moisture was removed from the gas sample by a water-cooled condenser so that the fixed gas analysis is on a dry basis.

The fixed gas composition of the gas sample was determined using a Shimadzu Model 3BT analyzer instead of the Fyrite or Orsat analyzer prescribed in Method 3. The Shimadzu instrument employs a gas chromatograph and a thermal conductivity detector to determine the fixed gas composition of the sample. Calibration of the Shimadzu analyzer was conducted according to the procedures outlined in the QAPP, which involved analysis of one or more standards of appropriate composition immediately before or after sample analysis.

Continuous Monitoring

Continuous monitoring was performed at the incinerator outlet sampling location for O_2, CO_2, CO, NO_x, and THC. The continuous monitoring was performed throughout the 6 to 8 hour period that dioxin sampling was being conducted each test day. The primary intent of the continuous monitoring effort was to (1) observe fluctuations in flue gas parameters, and (2) provide an indication of combustion conditions. Sample acquisition was accomplished using an in-stack filter probe and a 30m (100-feet) heat-traced Teflon^R sample line connected to a mobile laboratory. The heat-traced sample line was maintained at a temperature of 149^{o}C (300^{o}F) to prevent condensation in the sample line. The stack gas sample was drawn through the filter and sample line using pumps located in or near the mobile laboratory. Sample gas for CO, CO_2, NO_x, and O_2 analysis was pumped through a sample gas conditioner, consisting of an ice bath and knockout trap, to remove moisture and thus provide a dry gas stream for analysis. A separate unconditioned gas sample was supplied to the THC analyzer for analysis on a wet basis.

An Anarad Model 412 non-dispersive infrared (NDIR) analyzer was used to measure CO and CO_2; a Beckman Model 755 paramagnetic analyzer was used to measure O_2; a TECO Model 10 analyzer was used to measure NO_x; and a Beckman Model 402 flame ionization analyzer was used to measure THC. Calibration of the continuous monitors was performed according to the procedures outlined in the QAPP. These procedures included a three point (two upscale plus zero) linearity check on the first test day, single point and zero point calibration checks daily, and single point drift checks at the end of each test day.

6.2 LIQUID/SLURRY SAMPLES

The only liquid or slurry sample collected at Site SSI-B was scrubber system blowdown. The sample was taken from a tap valve on a stream consisting of the combined effluents from the venturi scrubber and the subcooler. Grab samples of scrubber blowdown were taken hourly during each MM5 test run. The grab samples were either composited for weight percent solids determination or filtered to provide composite solids and aqueous filtrate samples for dioxin/furan analysis.

To acquire the samples, the tap valve was fitted with a 1.2 m (4 ft) length of 1/4-inch Teflon^R tubing as shown in Figure 6-5. The sample was collected by placing the tubing in the sample jar and opening the valve to admit a moderate flow of slurry. The conduit line was flushed before the sample was taken and covered with hexane-rinsed foil between sampling times.

Hourly grab samples of scrubber blowdown were filtered using the apparatus shown schematically in Figure 6-6. The apparatus consisted of a pressure filtration vessel, Whatman^R No. 42 filters, a tank of high-purity nitrogen, a two-stage regulator, and a container for filtrate collection. Approximately 2 liters of scrubber blowdown slurry were filtered each hour. One liter at a time was poured into the pressure vessel and the vessel was slowly pressurized with the nitrogen to a maximum pressure of 50 psig. The time required to filter the two liters was approximately 20 to 30 minutes.

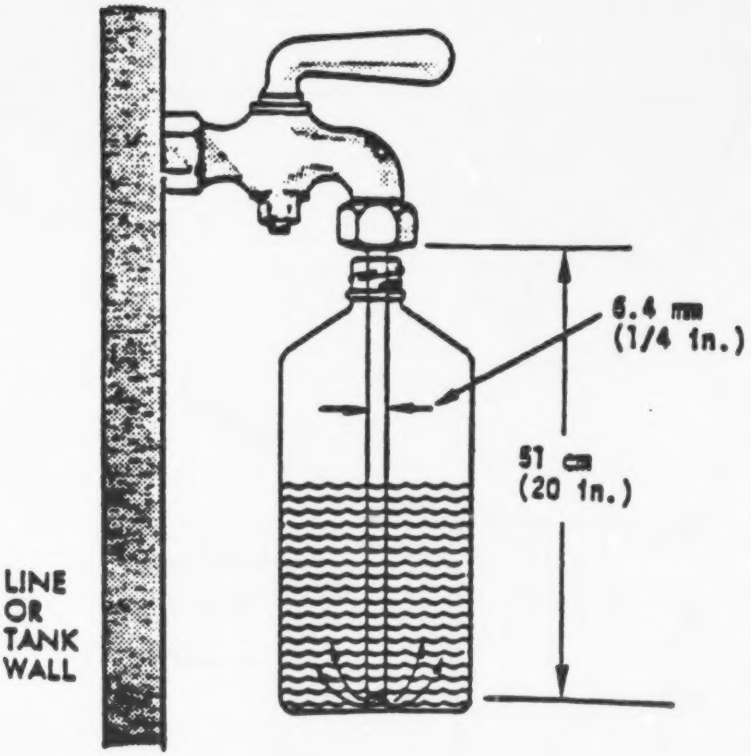

6.4 mm
(1/4 in.)
51 cm
(20 in.)
LINE
OR
TANK
WALL

FIGURE 6-5. SCHEMATIC OF TAP SAMPLING

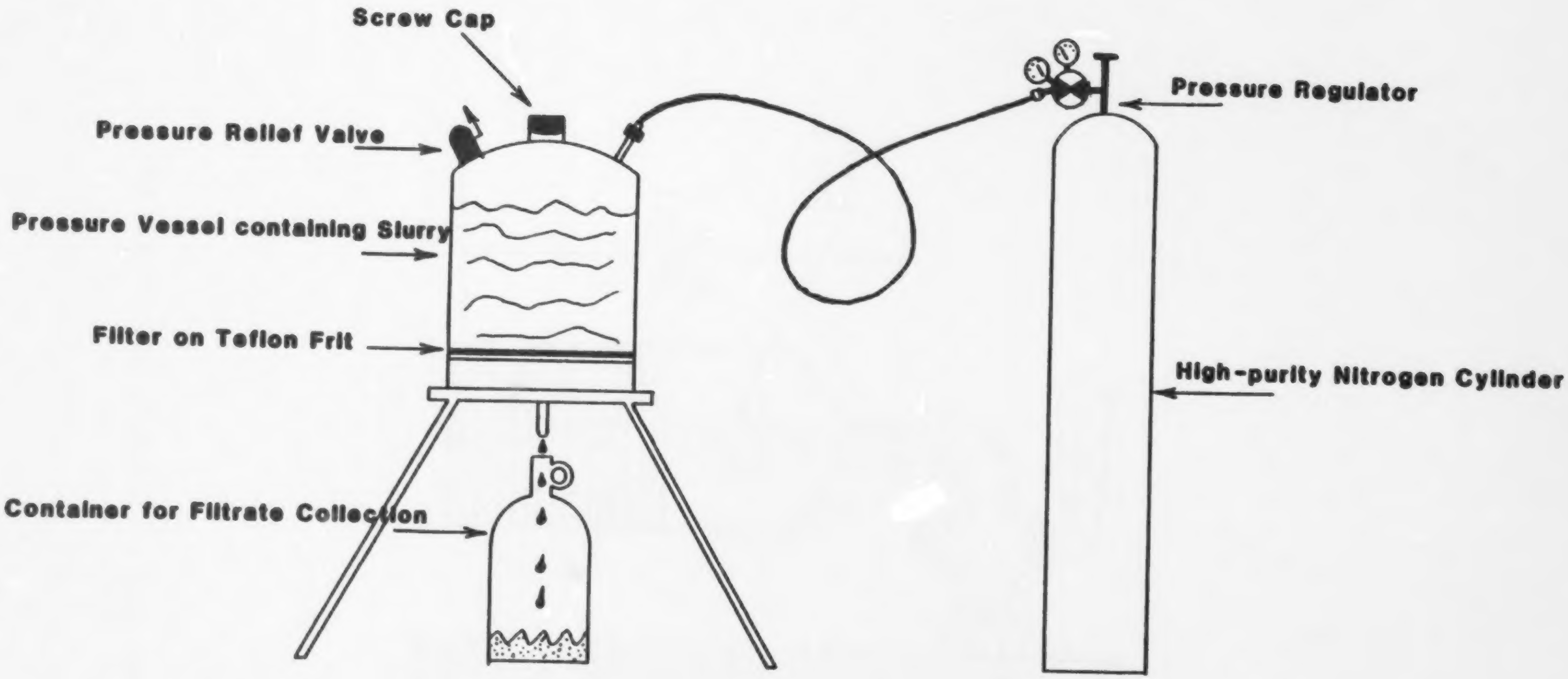

Screw Cap
Pressure Relief Valve
Pressure Vessel containing Slurry
Filter on Teflon Frit
Container for Filtrate Collection
Pressure Regulator
High-purity Nitrogen Cylinder

Figure 6-6. APPARATUS FOR PRESSURE FILTRATION OF SCRUBBER BLOWDOWN SLURRY

The filters used to separate the scrubber solids and aqueous filtrate have a rated collection efficiency of greater than 99 percent for particles larger than 3 microns. To minimize the required filtering time, the filters were replaced after every two liters of scrubber blowdown were filtered. The used filters and collected solids were removed from the pressure device with pre-cleaned teflon-coated tweezers and placed in a precleaned Petri dish.

6.3 SOLIDS SAMPLING

Three types of solid samples were collected at Site SSI-B: sludge feed, incinerator bottom ash, and soils from the plant property. Sampling procedures and locations are discussed below.

Sludge Feed Sampling

Sludge feed samples were collected from the conveyor belt feeding the incinerator. Grab samples were collected hourly by catching 500 mg of sludge in a glass jar as it fell from the conveyor into the incinerator. The grab samples were composited in a precleaned stainless steel bucket by mixing with a potato masher. Composite sludge feed samples were analyzed for dioxin, furan, and dioxin precursors.

Incinerator Bottom Ash Sampling

Incinerator bottom ash samples were taken hourly at the point of ash discharge from the incinerator using a precleaned metal scoop. Hourly samples for each MM5 test run were composited in a precleaned metal bucket and later analyzed for dioxin and furan content.

Soil Sampling

The soil sample for Site SSI-B consisted of a composite of 10 samples. Traditional wind patterns, as established by wind direction data provided by the plant, and routes normally taken by trucks hauling the ash were used as criteria for determining the soil sample location. All 10 samples were collected from a single grassy area approximately 0.25 miles from the incineration stacks and ash handling station. This area ran parallel to the road normally taken by trucks hauling ash for disposal. The soil samples were collected using a bulb planter which was pushed approximately 3 inches into the soil. The sample was first placed in a pre-cleaned stainless steel bucket and then transferred with hexane-rinsed aluminum foil to amber glass sample jars.

7.0 ANALYTICAL PROCEDURES

Laboratory procedures used to quantify dioxins/furans and dioxin/furan precursors in the Tier 4 samples are described in this section. MM5 train samples were analyzed by two of EPA's Troika laboratories for dioxin/furan content. Procedures used for these analyses are described in detail in the Analytical Procedures and QA Plan for the Analysis of Tetra through Octa CDDs and CDFs in samples from Tier 4 Combustion and Incineration Processes (addendum to EPA-600/3-85-019, April 1985). These procedures are summarized in Section 7.1.

Sludge feed samples from Site SSI-B were analyzed by Radian to determine concentrations of chlorinated phenols (CP), chlorobenzenes (CB), polychlorinated biphenyls (PCBs), and total chlorine. Procedures used for these analyses are detailed in Section 7.2.

7.1 DIOXINS/FURANS

The analytical procedures summarized in this section were used by Troika for dioxin/furan analysis of MM5 train samples from Site SSI-B. Samples consisting of organic solvents, aqueous solutions, and solids were prepared for analysis using slightly different procedures. The organic solvent samples consisted of rinses from the MM5 probe, nozzle, filter housing and condenser coil. Aqueous samples consisted of impinger catch solutions, and solid samples included filters and XAD resin. Isotopically-labeled surrogate compounds were added to all samples prior to extraction to allow determination of method efficiency and for quantification purposes.

Organic liquid samples (e.g., acetone and methylene chloride-based MM5 train rinses) were concentrated using a nitrogen blowdown apparatus. The residue, which contained particulate matter from the MM5 train probe and nozzle, was combined with the filter and handled as a solid sample. Solid samples were extracted with benzene in a Soxhlet apparatus for a period of at least 16 hours. The extract was concentrated by nitrogen blowdown and subjected to chromatographic cleanup procedures.

Aqueous solutions (e.g., MM5 train impinger samples) were extracted with hexane by vigorous shaking for a three hour period. This extraction procedure was repeated three times, with the organic fractions ultimately being combined and concentrated for chromatographic cleanup.

Aqueous solutions (e.g., MM5 train impinger samples) were extracted with hexane by vigorous shaking for a three hour period. This extraction procedure was repeated three times, with the organic fractions ultimately being combined and concentrated for chromatographic cleanup.

The cleanup procedure involved using liquid chromatographic columns to separate the compounds of interest from other compounds present in the samples. Four different types of columns were used: a combination acid and base modified silica gel column, a basic alumina column, a PX-21 carbon/celite 545 column and a silica/diol micro column. These were used in successive steps, with the last two being used only if necessary.

The cleaned samples were analyzed using high resolution gas chromatography/high resolution mass spectrometry (GC/MS). Conditions for the analyses were as follows:

Gas Chromatograph - Injector configured for capillary column, splitless injection, injector temperature 280°C, helium carrier gas at 1.2 ml/min, initial column temperature 100°C: final column temperature 240°C, interface temperature 270°C.

Mass Spectrometer - Varian/MAT Model 311A, electron energy 70ev, filament emission 1MA, mass resolution 8000 to 10,000, ion source temperature 270°C.

7.2 DIOXIN/FURAN PRECURSORS

Feed samples for Site SSI-B were analyzed by Radian/RTP for chlorophenols (CP), chlorobenzenes (CB) and polychlorinated biphenyls (PCBs) by GC/MS and total chlorine by Parr Bomb combustion followed by ion chromatography. Analytical procedures are discussed in the following sections.

7.2.1 GC/MS Analyses

The analytical procedures used for determining CP, CB, and PCB concentrations in feed samples are modified versions of procedures typically used for the analysis of MM5 train components. These procedures involve initial extraction of the sample with an appropriate solvent, preliminary separation of the compounds of interest by solvent partitioning and liquid chromatography, and analysis of the processed fractions. Solutions containing

CB and PCB are injected directly into the GC/MS, and solutions containing CP are derivatized prior to injection. Details on the procedures used for Site SSI-B samples are provided in the sections below.

7.2.1.1 Sample Preparation. A flow chart for the sample preparation procedure used for Site SSI-B feed samples is shown in Figure 7-1. The first step in the procedure involved adding labeled surrogate compounds to provide a measure of extraction method efficiency. The next step involved adding a mixture of 50/50 $MeCl_2$/Hexanes to the sample and sonicating the sample for 30 minutes. The sonicated sample was filtered and the filtrate was extracted three times in a separatory funnel with 50 ml 0.5 N NaOH and the aqueous and organic fractions were saved for derivatization and/or further cleanup. The aqueous fraction (or acids portion) was acidified to pH 2.0 with 1:1 H_2SO_4 and then extracted three times with 50 ml $MeCl_2$. The $MeCl_2$ from this extraction was dried with anhydrous Na_2SO_4, exchanged to benzene, and concentrated using a nitrogen blowdown apparatus. Acetylation of any CP present in the sample involved the following steps:

1. 2.0 mL isooctane, 2.0 mL acetonitrile, 50 uL pyridine, and 20 uL acetic anhydride were added to the extract. The test tube containing the extract was placed in a 60°C water bath for 15 minutes and was shaken 30 seconds every 2 minutes.
2. 6 mL of 0.01 N H_3PO_4 to the test tube, and the sample was agitated for 2 minutes on a wrist action shaker.
3. The organic layer was removed and the quantitation standard was added. The sample was concentrated in a Reacti-Vial at room temperature (using prepurified N_2) to 1 mL prior to GC/MS analysis.

Cleanup of the organic (or base/neutrals) layer from the first 0.5 N NaOH extraction involved successively washing the extract with concentrated H_2SO_4 and double-distilled water. The acid or water was added in a 20 mL portion and the sample was shaken for four minutes. After the aqueous (or acid) and organic layers were completely separated, the acid layer was discarded. The acid washing procedure was repeated until the acid layer was colorless. The organic fraction from the final wash was dried with anhydrous Na_2SO_4,

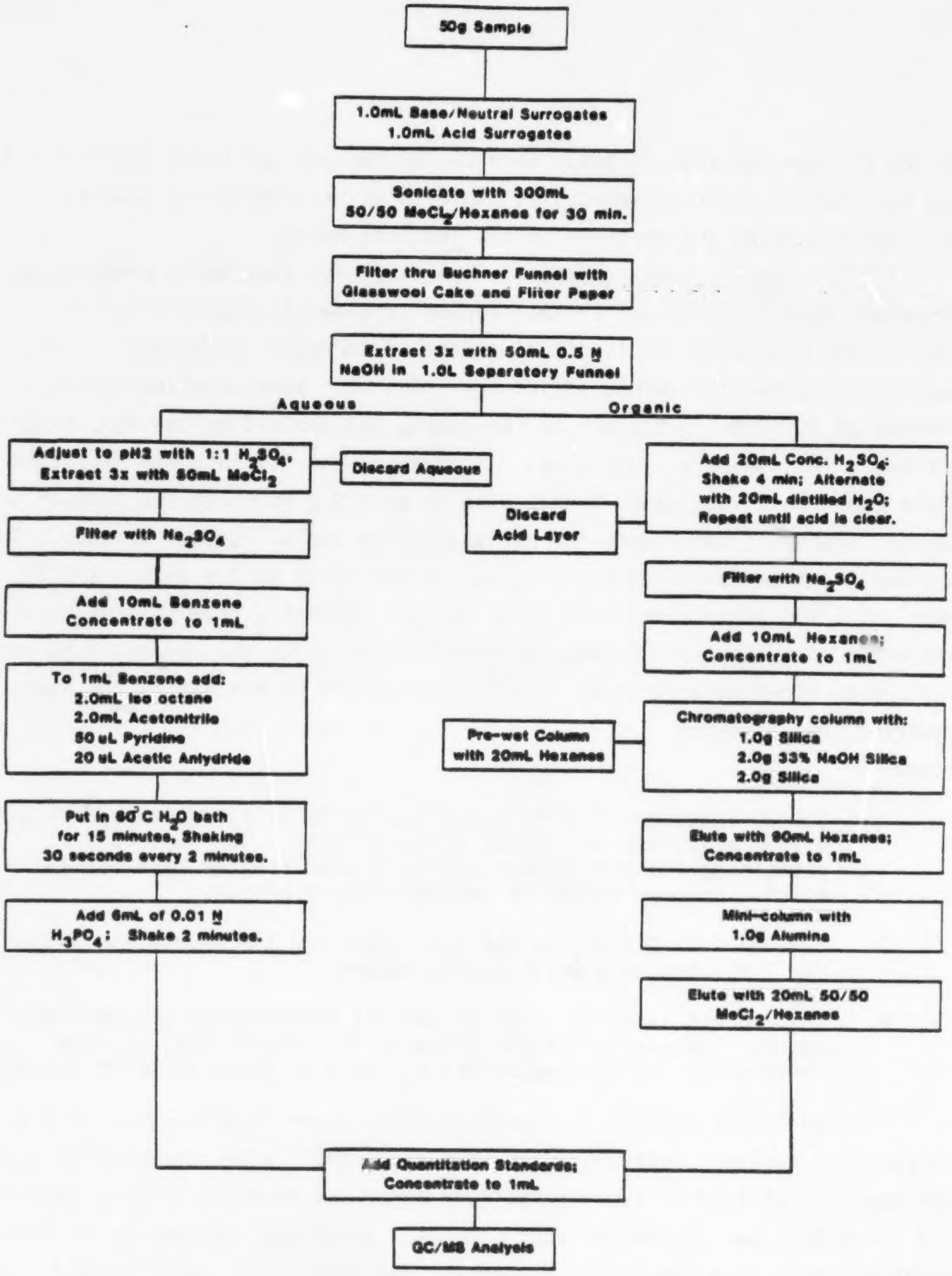

50g Sample
1.0mL Base/Neutral Surrogates
1.0mL Acid Surrogates
Sonicate with 300mL
50/50 $MeCl_2$/Hexanes for 30 min.
Filter thru Buchner Funnel with
Glasswool Cake and Filter Paper
Extract 3x with 50mL 0.5 N
NaOH in 1.0L Seperatory Funnel
Aqueous
Organic
Adjust to pH2 with 1:1 H_2SO_4;
Extract 3x with 50mL $MeCl_2$
Discard Aqueous
Filter with Na_2SO_4
Add 10mL Benzene
Concentrate to 1mL
To 1mL Benzene add:
2.0mL iso octane
2.0mL Acetonitrile
50 uL Pyridine
20 uL Acetic Anlydride
Put in 60°C H_2O bath
for 15 minutes, Shaking
30 seconds every 2 minutes.
Add 6mL of 0.01 N
H_3PO_4: Shake 2 minutes.
Add 20mL Conc. H_2SO_4;
Shake 4 min; Alternate
with 20mL distilled H_2O;
Repeat until acid is clear.
Discard
Acid Layer
Filter with Na_2SO_4
Add 10mL Hexanes;
Concentrate to 1mL
Pre-wet Column
with 20mL Hexanes
Chromatography column with:
1.0g Silica
2.0g 33% NaOH Silica
2.0g Silica
Elute with 90mL Hexanes;
Concentrate to 1mL
Mini-column with
1.0g Alumina
Elute with 20mL 50/50
$MeCl_2$/Hexanes
Add Quantitation Standards;
Concentrate to 1mL
GC/MS Analysis

FIGURE 7-1. SAMPLE PREPARATION FLOW DIAGRAM FOR SITE SSI-B PRECURSOR ANALYSIS

exchanged to hexane and concentrated. Final cleanup of the sample by column chromatography involved the following procedure.

A glass macro-column, 20 mm o.d. x 230 mm in length, tapered to 6 mm o.d. on one end was prepared. The column was packed with a plug of silanized glass wool, followed successively by 1.0 g silica, 2.0 g silica containing 33% (w/w) 1 N NaOH, and 2.0 g silica. The concentrated extract was quantitatively transferred to the column and eluted with 90 mL hexane. The entire eluate was collected and concentrated to a volume of 1 mL in a centrifuge tube.

A disposable liquid chromatography mini-column was constructed by cutting off a 5-mL Pyrex disposable pipette at the 2.0 mL mark and packing the lower portion of the tube with a small plug of silanized glass wool, followed by 1 g of Woehlm basic alumina. The alumina had been previously activated for at least 16 hours at 600°C in a muffle furnace and cooled in a desiccator for 30 minutes just before use. The concentrated eluate was quantitatively transferred onto the liquid chromatography column. The centrifuge tube was rinsed consecutively with two 0.3-mL portions of a 3 percent $MeCl_2$: hexane solution, and the rinses were transferred to the liquid chromatography column.

The liquid chromatography column was eluted with 20 mL of a 50 percent (v/v) $MeCl_2$:hexane solution, and the eluate was concentrated to a volume of approximately 1 mL by heating the tubes in a water bath while passing a stream of prepurified N_2 over the solutions. The quantitation standard was added and the final volume was adjusted to 1.0 mL prior to GC/MS analysis.

7.2.1.2 Analysis. Analyses of the feed sample extracts for CP, CB and PCB's present were performed with a Finnigan Model 5100 mass spectrometer using selected ion monitoring. A fused silica capillary column was used for chromatographic separation of the compounds of interest. Analytical conditions for the GC/MS analysis are shown in Table 7-1.

Tuning of the GC/MS was performed daily as specified in the Tier 4 QA Project Plan. An internal-standard calibration procedure was used for sample quantitation. Compounds of interest were calibrated against a fixed concentration of either d_{12}-chrysene (for CB, PCB) or d_8-naphthalene (for CP). Components of the calibration solution are shown in Table 7-2. For

TABLE 7-1. INSTRUMENT CONDITIONS FOR GC/MS PRECURSOR ANALYSES

Parameter	Chlorobenzenes/ Polychlorinated biphenyls	Chlorophenols
Column	30 m WB DB-5 (1.0 u film thickness) fused silica capillary	
Injector Temperature	290°C	290°C
Separator Oven Temperature	290°C	290°C
Column Head Pressure	9 psi	9 psi
He flow rate	1 mL/min	1 mL/min
GC program	40(4)-290°C, 10°/min & hold	40(1)-290°C, 12°/min & hold
Emission Current	0.50 mA	0.50 mA
Electron Energy	70 eV	70 eV
Injection Mode	Splitless 0.6 min, then 10:1 split	
Mode	Electron ionization, Selected Ion Monitoring	

TABLE 7-2. COMPONENTS OF THE CALIBRATION SOLUTION

Base/Neutrals	Acids
4-chlorobiphenyl	2,5-dichlorophenol
3,3'-dichlorobiphenyl	2,3-dichlorophenol
2,4',5-trichlorobiphenyl	2,6-dichlorophenol
3,3'4,4'-tetrachlorobiphenyl	3,5-dichlorophenol
2,2',6,6'-tetrachlorobiphenyl	3,4-dichlorophenol
2,2,4,5,6-pentachlorobiphenyl	2,3,5-trichlorophenol
2,2',4,4',5,5'-hexachlorobiphenyl	2,3,6-trichlorophenol
2,2',3,4,4',5',6-heptachlorobiphenyl	3,4,5-trichlorophenol
2,2',3,3',4,4',5,5'-octachlorobiphenyl	2,4,5-trichlorophenol
2,2',3,3',4,4',5,6,6'-nonachlorobiphenyl	2,3,4-trichlorophenol
decachlorobiphenyl	2,3,5,6-tetrachlorophenol
p-dichlorobenzene	pentachlorophenol
1,2,4-trichlorobenzene	d_6-phenol (SS)
1,2,3,5-tetrachlorobenzene	d_4-2-chlorophenol (SS)
pentachlorobenzene	$^{13}C_6$-pentachlorophenol (SS)
hexachlorobenzene	d_8-naphthalene (QS)
d_4-1,4-dichlorobenzene (SS)[1]	2,4,6-tribromophenol (QS)
3-bromobiphenyl (SS)	d_{10}-phenanthrene (QS)
2,2',5,5'-tetrabromobiphenyl (SS)	d_{12}chrysene (QS)
2,2',4,4',6,6'-hexabromobiphenyl (SS)	
octachloronaphthalene (QS)[2]	
d_{10}-phenanthrene (QS)	
d_{12}-chrysene (QS)	

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[1] Surrogate standard.

[2] Quantitation standard.

multi-point calibrations, this solution was injected at concentrations of 10, 50, 100, and 150 ng/ul.

Compound identification was confirmed by comparison of chromatographic retention times and mass spectra of unknowns with retention times and mass spectra of reference compounds. Since the selected ion monitoring technique was necessary for the samples analyzed, care was taken to monitor a sufficiently wide mass region to avoid the potential for reporting false positives.

The instrument detection limit for the analytes of interest (i.e., CP, CB, and PCB) was estimated to be approximately 500 pg on column. For a 50 g sample and 100 percent recovery of the analyte, this corresponds to a feed sample detection limit of 10 ppb.

7.3 TOTAL CHLORIDE ANALYSIS

Total chloride concentrations in feed samples were determined by Parr Bomb combustion followed by ion chromatography (IC). A 0.5g sample was placed in the Parr Bomb with 10 mL of a 50 g/L Na_2CO_3 solution. After combustion of the samples according to standard procedures (ASTM 2015), the contents of the bomb were rinsed into a 100 mL flask and diluted to 100 mL. The resulting solution was analyzed for chloride concentration (Cl^-) by IC using standard anion conditions. For samples difficult to combust (such as sludges), 25 drops of paraffin oils were added to the bomb prior to combustion.

8.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

This section summarizes the results of quality assurance and quality control (QA/QC) activities for Site SSI-B. The flue gas and ash dioxin/furan data for this site were generally within the QC specifications presented in the Tier 4 QAPP. All of the surrogate recoveries for labeled TCDD's were within the specified limits of 50 to 120 percent. All of the surrogate recoveries for the labeled hepta- and octa-CDD's were within the specified limits of 40 to 120 percent. The results of the analysis of the fortified laboratory QC sample show excellent recoveries with all values well within the accuracy objective of 60 to 140 percent.

The dioxin/furan precursor analysis of the feed samples was not as accurate as the dioxin/furan homologue analysis. Surrogate recoveries were generally below the specified QC limits of ± 50 percent. However, despite the low surrogate recoveries, the dioxin/furan precursor results are considered a reasonable approximation of the true precursor concentration in the feed samples.

The following sections summarize the results of all Site SSI-B QA/QC activities. Manual gas sampling methods are considered in Section 8.1 and continuous emission monitoring and molecular weight determinations are considered in Section 8.2. Results of QA audits and laboratory QA/QC activities are summarized in Sections 8.3 and 8.4, respectively.

8.1 MANUAL GAS SAMPLING

Manual gas sampling methods used at Site SSI-B included Modified Method 5 (MM5) and EPA Methods 1 through 4. These methods are discussed in Section 6.0. Quality assurance and quality-control (QA/QC) activities for the manual methods centered around (1) equipment calibration, (2) glassware precleaning, and (3) procedural QC checks and (4) sample custody procedures. Key activities and QC results in each of these areas are discussed in this section. Also discussed are problems encountered that may have affected data quality.

Pretest calibrations or inspections were conducted on pitot tubes, sampling nozzles, temperature sensors and analytical balances. Both pre- and

TABLE 8-1. GLASSWARE PRECLEANING PROCEDURE

NOTE: USE DISPOSAL GLOVES AND ADEQUATE VENTILATION

1. Soak all glassware in hot soapy water (Alconox^{o}) 50^{o}C or higher.
2. H_2O rinse (X3)[a].
3. Distilled/deionized H_2O rinse (X3).
4. Chromerge^{R} rinse if glass, otherwise skip to 6.
5. High purity liquid chromatography grade H_2O rinse (X3).
6. Acetone rinse (X3), (pesticide grade).
7. Hexane rinse (X3), (pesticide grade).
8. Oven dry (110^{o}C - 2 hours).
9. Cap glassware with clean glass plugs or hexane rinsed aluminum foil.

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[a] (X3) = three times

post-test calibrations were also performed on the dry gas meter. All of this equipment met the calibration criteria specified in the QAPP. The pre- and post-test dry gas meter calibrations differed by 0.3 percent.

An extensive precleaning procedure was implemented for all sample train glassware and sample containers. This cleaning procedure, which is outlined in Table 8-1, was implemented to minimize the potential for sample contamination with substances that may interfere with the analysis for dioxins and furans. All sample train glassware was capped with foil prior to use and stored in a dust free environment. A clean sample trailer was maintained for train assembly and sample recovery.

Procedural QC activities during manual gas sampling focused on:

- visually inspecting equipment,
- utilization of sample train blanks,
- ensuring the proper location and number of traverse points,
- conducting pre-test, port change, and post-test sample train leak checks,
- maintaining proper temperat[illegible]t the filter housing, sorbent trap and impinger train,
- maintaining isokinetic sampling rates, and
- recording all data on preformatted data sheets.

Results of isokinetic calculations for valid MM5 test runs are shown with EPA Method 4 results in Table 8-2. As shown in Table 8-2, the average isokinetic sampling rate for the MM5 and sampling trains achieved the QA objective of ± 10 percent for all three test runs.

Sample custody procedures used during this program emphasized careful documentation of the sample collected and the use of chain-of-custody records for samples to be transported. Steps taken to identify and document samples collected included labelling each sample with a unique alphanumeric code and logging the sample in a master logbook. All samples shipped to Troika or returned to Radian were also logged on chain-of-custody records that were signed by the sampler at shipment and then by the receiving laboratory when the samples arrived. Each sample container was also sealed with a chain-of-custody seal so that the container could not be opened without tearing the seal.

TABLE 8-2. RESULTS OF ISOKINETIC CALCULATIONS AND MOISTURE DETERMINATIONS

Run Number	Modified Method 5	
	Isokinetics (%)[a]	Moisture (%)
1	109	3.38
3	106	4.76
5	108	3.01

[a] QA objective for isokinetics was 100 ± 10 percent.

8.2 CONTINUOUS MONITORING/MOLECULAR WEIGHT DETERMINATION

Flue gas parameters monitored continuously during the M55 test runs included CO, CO_2, O_2, total hydrocarbons (THC) and NO_x. Concentrations of CO_2, O_2, and N_2 were also determined for integrated bag samples of stack gas. Quality control results for these analyses are discussed in this section.

Drift check and quality control standard analyses results for the continuously monitored flue gas parameters are summarized in Table 8-3. The acceptance criterion for drift checks was an instrument drift within ±10 percent. All data reduction was performed assuming a linear drift of instrument response over the test day. The only calibration drift exceeding the acceptance criterion was for CO_2 during Run 3. The instrument showing the smallest drift was the O_2 monitor.

The quality control standards for this program consisted of mid-range standards that were not used for instrument calibration but were analyzed immediately after calibration to provide data on day-to-day instrument variability. The acceptance criterion for each control standard was agreement with ±10 percent of the running mean value. All of the instruments met this criterion on each test day except for the CO monitor prior to Run 1 and the NO_x monitor prior to Run 3.

Molecular weight was determined by analyzed integrated bag samples of stack gas for CO_2, O_2, and N_2. Quality control for this analysis involved duplicate analyses of calibration gases immediately before and after sample analysis. Analysis of the calibration gases was repeated until two consecutive analyses within ±5 percent were obtained. This same criteria of ±5 percent applied to duplicate analyses required for each sample quantitation. These criteria were met for all molecular weight determinations.

8.3 SYSTEMS AND PERFORMANCE AUDITS

Systems and performance audits of the field testing effort at Site SSI-B were performed by one of Radian's QA coordinators for Tier 4. Results of the audits are discussed below.

8.3.1 Systems Audit

The systems audit focused on observing the procedures and techniques used by the sampling crew, a review of documentation for completeness, and a check

Table 8-3. SUMMARY OF DRIFT CHECK AND CONTROL STANDARD RESULTS

			Drift Check			QC Standard			
Test Date	Test Run	Parameter	Input Concentration	Instrument Drift, %[a]	Meets QC?[b]	Input Concentration	Output Concentration	Difference From Running Mean, %	Meets QC?[c]
11/15/84	1	O_2	21.2	-0.37	Yes	9.55	9.61	0.0	Yes
11/17/84	3	O_2	21.2	-1.47	Yes	9.55	9.58	-0.1	Yes
11/19/84	5	O_2	21.2	0.31	Yes	9.55	9.51	-0.8	Yes
11/15/84	1	CO	5430	0.69	Yes	2060	2596	18.6	No
11/17/84	3	CO	5430	8.46	Yes	2060	2421	8.1	Yes
11/19/84	5	CO	5430	-5.79	Yes	2060	2503	9.4	Yes
11/15/84	1	CO_2	17.6	-3.19	Yes	12.8	12.5	-2.7	Yes
11/17/84	3	CO_2	17.6	24.1	No	12.8	12.7	-1.3	Yes
11/19/84	5	CO_2	17.6	-18.5	No	12.8	12.8	-0.8	Yes
11/15/84	1	NO_x	816	1.67	Yes	308	336	d	d
11/17/84	3	NO_x	816	-0.71	Yes	84.6	113	21.7	No
11/19/84	5	NO_x	816	1.61	Yes	84.6	96.1	2.5	Yes
11/15/84	1	THC	90.0	2.37	Yes	308	295	-0.14	Yes
11/17/84	3	THC	90.0	5.46	Yes	60.3	59.7	-0.56	Yes
11/19/84	5	THC	90.0	-0.18	Yes	60.3	60.8	0.92	Yes

[a] Instrument drift is defined as the percent difference between the instrument response to the input concentration at the beginning and end of the test run.

[b] QC criterion was instrument drift within ±10 percent.

[c] QC criterion was output concentration within ±10 percent of the running mean concentration for this test site.

[d] No other data at this QC standard concentration are available for comparison.

of team adherence to the QC protocol prescribed by the Quality Assurance Project Plan (QAPP). The completed systems audit checklist presented in Figure 8-1 shows the results of the systems audit for the MM5 sampling activities. No significant problems with the MM5 procedures were observed.

An analytical problem with the apparatus used for filtering the scrubber blowdown was discovered and corrected by the sampling crew during the systems audit. Some of the solids in the scrubber blowdown samples were not being removed by the apparatus because the filters were too small. The problem was solved by obtaining properly sized filters. A potential for incomplete documentation of testing events was also observed. The sampling task leader typically made entries into the daily events log on the evening of the test day with assistance from one other sampling crew members. Due to the distance between sampling locations and the size of the sampling effort, it may not always have been possible for the task leader to record all of the events that might have affected interpretation of the data. Documentation of the events could be improved if each member of the sampling crew was required to keep a current individual events log (pocket size) to be reviewed by the task leader each evening.

8.3.2 Performance Audit

The performance audit consisted of challenging various components of the sampling and analytical systems with independent standards. Gas standards containing components representative of the flue gas were used to audit the continuous emissions monitoring (CEM) system. The gas standards were obtained from Scott Environmental; the standards concentrations were certified to within ±1 percent by the vendor. At least one additional standard for each parameter was obtained from the EPA Repository as a cross check. Audit gases were delivered through the sample conditioning system used during testing though not through the heat-traced line between the sample probe and the conditioner. The results of the CEM audit are presented in Table 8-4. Generally, the audit results showed the CEM instrumentation to be calibrated well within the specified program accuracy objectives. There were two exceptions. The Anarad CO/CO_2 instrument exhibited a great deal of signal noise and high bias for both channels with the CO channel exceeding the ± 2% accuracy target by a small margin. There was a degree of non-linearity below

Site: SSI-B

Date: 11/15/84

Contract: National Dioxin Study Tier 4

Auditor: K. Rozacky

Yes	No	Comments	Operation
			PRESAMPLING PREPARATION
X			1. Knowledge of process conditions.
X			2. Calibration of pertinent equipment prior to each field test (especially nozzles, dry gas meter, termperature sensors).
X			3. Appropriate number and location of sample traverse points.
X			4. Filter properly handled during pretreatment and loading.
X			5. XAD traps properly handled during pretreatment and loading.
X		1/8" sample 6 hrs @ scfm	6. Appropriate size nozzle selected per isokinetic sampling and gas velocity considerations.
X			7. Adequate identification procedures used for filters.
X			8. Adequate identification procedures for XAD traps.
X		10/30/84 Lot 9/02684	9. Date of precleaning for XAD resin.
x		9/10/84 33#934 AH FILTERS (LOT #2)	10. Date of precleaning for filter elements.
X			11. Sampling train properly assembled.
X			12. Adequate facilities, spare parts, and support equipment available.

Figure 8-1. COMPLETED SYSTEMS AUDIT CHECKLIST

Yes	No	Comments	Operation
			SAMPLING OPERATIONS
X		<.02 cfm	1. Initial leak check performed.
X			2. Probe maintained at proper temperature (> 248°F).
X			3. Filter holder maintained at proper temperature (248 ± 25°F).
X			4. Appropriate data recorded during sampling run.
X			5. Proper flow rate maintained for isokinetic sampling at each point (within ±10%).
X			6. Probe placed into and removed from stack with care taken to avoid scraping port and/or duct walls.
X			7. Sample train leak checked at conclusion of run.
			POSTSAMPLING OPERATIONS
X			1. Sufficient sample volume collected.
X			2. Nozzle rinse performed properly (acetone, hexane x 3)
X			3. Proper handling procedures observed in unloading filter holder.
X			4. Field blanks for filter and XAD submitted for analysis.
X			5. Chain-of-custody documentation completed for each component of train.
X			6. Data and pertinent observations properly recorded.

Figure 8-1. COMPLETED SYSTEMS AUDIT CHECKLIST (continued)

Yes	No	Comments	Operation
			POSTSAMPLING OPERATIONS (Continued)
X		COMPAQ w/MM5 SOFTWARE PROGRAM	7. Adequate data reduction procedures.
X		UNCAPPED	8. Blank train constructed, allowed to sit for at least 3 hours, disassembled and submitted for analysis.

COMMENTS: Moisture determination done as part of MM5 -weight gain in impingers 1, 2, 3 as H_2O + siliga gel weight gain in 4.

Figure 8-1. COMPLETED SYSTEMS AUDIT CHECKLIST (continued)

Table 8-4. CONTINUOUS EMISSION MONITORING SYSTEM (CEM) AUDIT RESULTS

Parameter Instrument Method	Sample ID	True Concentrations (Units)	Measured Concentration (Units)	Relative Error (%)	Accuracy Target (%)
		(ppm)	(ppm)		
THC (as propane) Beckman 402 FID	1-A	0.0	1.11	-	
	14-A[a]	9.63	9.84	2.2	±25
	12-A	20.50	19.50	-4.9	
	13-A	80.40	75.16	-6.5	
		(ppm)	(ppm)		
CO Anarad AR 400 NDIR	1-B	0.0	-0.8	-	
	3-A	60.5	115.4	90.7	
	2-A	259.0	325.9	25.8	±20
	4-A	1002.0	1239.5	23.7	
	5-A	2491.0	2933.8	17.8	
	6-A[a]	2480.0	3048.4	22.9	
		(%)	(%)		
CO$_2$ Anarad AR 400 NDIR	1-B	0.0	0.45	-	
	8-A	2.01	2.16	7.5	
	6-A[a]	7.61	8.99	18.1	±20
	11-A[a]	10.50	12.01	14.4	
		(%)	(%)		
O$_2$ Beckman 755 Paramagnetic	11-A[a]	0.0	-0.05	-	
	9-A	4.015	4.23	5.3	±20
	10-A[a]	7.99	8.40	5.1	
	8-A	9.96	10.34	3.8	
		(ppm)	(ppm)		
NO$_x$ Thermo Electron Series 10 Chemiluminescence	1-C	0.0	1.3	-	
	18-C[a]	51.7	62.6	21.1	
	17-A	100.0	121.5	21.5	
	16-A	225.0	279.5	24.2	±20
	15-A	705.0	795.9	12.9	
		(%)	(%)		
O$_2$ Shimadzu GC-3BT FID	8-A	9.96	10.11	1.5	±20
	7-A	15.10	15.18	0.6	
CO$_2$ Shimadzu GC-3BT FID	8-A	2.01	2.05	2.0	±20
	7-A	5.10	5.01	-1.7	

[a] EPA supplied gas standard

70 ppm CO; however, the majority of actual testing data was above 1000 ppm. Also, the Thermo Electron NO_x instrument also showed a high response bias exceeding the ± 20% accuracy target for this parameter. Both instruments did have linear response across the scale.

The Mettler PE 360 loading analytical balance was audited using a standard set of Class S weights. Accuracy was satisfactory. Results of the audit are presented in Table 8-5.

The dry gas meter (DGM) in console RAC #5, used to measure volumetric flow for the Modified Method 5 sample train, was audited by direct comparison to a transfer DGM which had been referenced to an independent wet test meter. A flow rate of approximately 0.4 cfm was used as a reference. Agreement between the two DGM's was within ± 2.7% based on three 15-minute runs exhibiting a coefficient of variation less than 1.3%. As part of the performance audit, a set of sample data was submitted to the sampling team for determination of velocity and volumetric flow rates, moisture content, and gas molecular weight. All requested calculations were accurately performed.

In summary, the performance audit showed that the accuracy targets were met except where noted and that those cases were not extreme. The systems audit found the sampling team competent and knowledgeable in their tasks, documentation complete and current, chain-of-custody procedures satisfactory, and the prescribed QC protocol meeting the program objectives.

8.4 LABORATORY ANALYSES

QA/QC data collected for the various laboratory analyses performed on Site SSI-B samples are discussed in this section. Dioxin/furan QC data are discussed in Section 8.3.1, precursor QC data are discussed in Section 8.3.2, and total chloride data are summarized in Section 8.3.3.

8.4.1 Dioxin/Furan QC Data

Surrogate recoveries for dioxin/furan analyses performed on Site SSI-B samples are presented in Table 8-6. All of the surrogate recoveries are within the target ranges of 50 to 120 percent for the labeled TCDD's and 40 to 120 percent for the labeled hepta and octa-CDD's.

Results for dioxin/furan blank samples and a QC (fortified spiked) sample are summarized in Table 8-7. Again, surrogate recoveries were all within the

TABLE 8-5. METTLER 360 (S/N C99712) BALANCE AUDIT RESULTS

Audit Weight (grams)	Measured Weight (grams)	Absolute Error (grams)[a]
0.00	0.00	--
0.05	0.05	0.00
0.50	0.50	0.00
1.00	1.00	0.00
5.00	5.00	0.00
10.00	9.99	-0.01
20.00	19.99	-0.01
50.00	49.97	-0.03
100.00	99.87	-0.13
150.00	149.82	-0.18
200.00	199.78	-0.22
455.10	454.80	-0.30

[a] Range of Error (g) -0.30 to 0.00, 95% Confidence Interval (g) -0.15 to -0.007

TABLE 8-6. SUMMARY OF SURROGATE RECOVERIES FOR DIOXIN/FURAN ANALYSES ON SITE SSI-B SAMPLES

		Surrogate Recoveries (percent)			
Compound	Spiked[a] Quantity (ng)	Run 1 MM5	Run MM5	Run 5[b] MM5 (aqueous)	Run 5[b] MM5 (XAD resin)
$^{37}Cl_4$-TCDD	5	78	92	106	NS[c]
$^{13}C_{12}$-TCDD	5	106	94	NS	102
$^{37}Cl_4$-Hepta-CDD	20	48	52	53	NS
$^{13}C_{12}$-Octa-CDD	20	99	79	NS	78

[a] Amount of compound spiked into each sample prior to extraction and analysis.
[b] The aqueous and XAD resin portions of this sample were analyzed separately.
[c] Compound not spiked into this sample.

TABLE 8-7. SUMMARY OF RESULTS FOR DIOXIN/FURAN BLANK SAMPLES AND FORTIFIED QC SAMPLES

Compound	Surrogate Recoveries, Percent		
	Field Blank	Laboratory Blank	Fortified QC Sample
$^{37}\mathrm{Cl}_4$-TCDD[a]	92	98	92
$^{13}\mathrm{C}_{12}$-TCDD[a]	102	94	92
$^{37}\mathrm{Cl}_4$ Hepta-CDD[b]	58	78	63
$^{13}\mathrm{C}_{12}$ Octa-CDD[b]	99	84	82
	Amount detected, ng (Amount spiked on fortified sample, ng)		
Dioxins			
2378 TCDD	ND[c]	ND	0.2 (0.4)
Other TCDD	ND	ND	ND (0)
Penta CDD	ND	ND	ND (0)
Hexa CDD	ND	ND	1.1 (1.6)
Hepta CDD	0.3	ND	2.0 (2.4)
Octa CDD	1.0	ND	2.4 (3.2)
Furans			
2378 TCDF	ND	ND	0.3 (0.4)
Other TCDF	ND	ND	ND (0)
Penta CDF	ND	ND	0.5 (0.8)
Hexa CDF	ND	ND	1.0 (1.6)
Hepta CDF	0.1	ND	1.8 (2.4)
Octa CDF	ND	ND	2.4 (3.2)

---

[a] Spiked at 5 ng in each sample.

[b] Spiked at 20 ng in each sample.

[c] ND = not detected. Detection limit ranged from 0.01 to 0.19 ng.

target ranges. The field blank and the laboratory blank were found to be clean with the exception of 1.0 ng of octa-CDD, 0.3 ng of hepta-CDD and 0.1 ng of hepta-CDF in the field blank. Comparison of measured and spiked quantities for the QC sample shows excellent recoveries for the unlabeled PCDD and PCDF, with all values well within the accuracy objective of 60 to 140 percent for this sample.

8.4.2 Precursor QC Data

Surrogate recovery efficiencies for six labeled compounds spiked into sludge feed samples are presented in Table 8-8. The recoveries vary considerably depending on the particular surrogate. Recoveries for the sludge feed samples ranged from 0 to 169 percent. With the exception of bromobiphenyl in the Run 1 sample, the surrogate recoveries were frequently below the 50 percent objective stated in the Tier 4 QA Project Plan and were below those generally considered achievable when analyzing for similar compounds in water or from MM5 train components. There are no directly comparable surrogate recovery values reported in the literature for samples similar to those analyzed for Site SSI-B. The cause of the high recovery for bromobiphenyl in the Run 1 sludge sample is unknown.

There are several reasons for the comparatively low precursor surrogate recoveries reported in the Tier 4 study for samples such as Site SSI-B feed samples. First, the complex nature of the samples required extensive clean-up procedures prior to GC/MS analysis, which increased the potential for losses of the surrogate compounds (and analytes) during sample preparation. Second, large sample sizes (25 to 50 g) were required to increase method sensitivity for the target analytes and to ensure that representative portions of the samples were analyzed. Due to the high cost of labeled surrogates, it was not desirable to spike the large sample sizes with surrogates in proportion to that normally used for smaller samples. Supplemental in-house laboratory studies showed that when sample size was restricted to 1 g and the amount of surrogate spiked was held fixed, surrogate recoveries improved considerably. Surrogate recoveries for Tier 4 samples and the results for small sample sizes are further discussed in the Tier 4 Engineering Analysis Report.

In spite of the relatively low surrogate recovery values for some of the feed samples, the resulting analytical sensitivity for the target analytes was

TABLE 8-8. SUMMARY OF SURROGATE RECOVERIES FOR DIOXIN PRECURSOR ANALYSES

Compound	Precursor Surrogate Recoveries (percent)[a] Sludge Feed Run 1	Sludge Feed Run 3	Sludge Feed Run 5
d_4-Dichlorobenzene	72	39	44
Bromobiphenyl	169	110	98
Tetrabromobiphenyl	118	78	85
d_6 - Phenol	10	10	8
d_4 - Chlorophenol	13	9	10
$^{13}C_6$ - Pentachlorophenol	3	5	ND

[a] Surrogates spiked at 200 ng each in 50 g sample.

ND = not detected.

considered acceptable for the purpose of this study. The instrumental detection limit ranged from about 100 to 500 picograms on-column for the 1 microliter of final extract injected into the GC/MS. At a method recovery efficiency of 100 percent for a 50 gram solid sample cleaned up to a final extract volume of 1 milliliter, the overall analytical sensitivity would be approximately 2 to 10 ppb in the solid sample. For sludge samples with surrogate recoveries as low as 3 percent, the overall analytical sensitivity of the method would still be 600 to 3000 ppb, or 0.6 to 3.0 ppm. Thus, even in a worst-case situation the analytical procedures used provide information on the precursor content of the feed samples down to the ppm level.

A single matrix spike was analyzed for the Site SSI-B feed samples. This sample showed 0 to 39 percent recovery for spiked chlorobenzenes and 19 to 111 percent for spiked chlorinated biphenyls and 2 to 14 percent for spiked chlorophenols. Results of laboratory blanks for the precursor analyses all showed no detectable levels of the target compounds.

8.4.3 Total Chlorine QC Data

Total chloride analyses were performed by Research Triangle Institute on three composite feed samples. Blank analysis values obtained for the Parr bomb combustion/ion chromatography technique were 36, 0, 56, and 18 ppm chloride. Data presented in Section 5 are blank corrected. A LECO coal sample containing 2600 ppm chloride was analyzed as a daily QC standard. Reported values were 2500, 2500, 2500, and 2400 ppm.

9.0 REFERENCES

1. Radian Corporation. National Dioxin Study Tier 4 - Combustion Sources. Draft Final Report prepared for U.S. Environmental Protection Agency, Research Triangle Park, N.C. EPA 450/4-84-014e, April 1985.

APPENDIX A
FIELD RESULTS

APPENDIX A-1

MODIFIED METHOD 5 AND EPA METHODS 1-4 FIELD RESULTS

```
          R A D I A N   S O U R C E   T E S T
          E P A   M E T H O D   2 - 5
          ( R A W   D A T A )
       PLANT                 : DIOXIN SITE #03
       PLANT SITE            :
       SAMPLING LOCATION     : UNIT    EXHAUST
       TEST #                : 03-MM5-01
       DATE                  : 11/15/84
       TEST PERIOD           : 0946-1358 (0946-1146 / 1158-1358)

     PARAMETER                             VALUE
     ---------                             -----

     Sampling time (min.)                   240 .
     Barometric Pressure (In.Hg)            29.18
     Sampling nozzle diameter (in.)         .12
     Meter Volume (cu.ft.)                  90.001
     Meter Pressure (in.H2O)                .445
     Meter Temperature (F)                  42.26
     Stack dimension (sq.in.)               671.9588
     Stack Static Pressure (in.H2O)        -.9
     Stack Moisture Collected (gm)          68.1
     Absolute stack pressure(in Hg)         29.11382
     Average stack temperature (F)          169.4894
     Percent CO2                            4.66
     Percent O2                             17.85
     Percent N2                             77.49
     Delps Subroutine result                38.20479
     DGM Factor                             .9945
     Pitot Constant                         .84
```

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```
          R A D I A N   S O U R C E   T E S T
          E P A   M E T H O D S   2 - 5
          F I N A L   R E S U L T S
      PLANT                : DIOXIN SITE #03
      PLANT SITE           :
      SAMPLING LOCATION    : UNIT     EXHAUST
      TEST #               : 03-MM5-01
      DATE                 : 11/15/84
      TEST PERIOD          : 0946-1358 (0946-1146 / 1158-1358)

          PARAMETER                  RESULT
          ---------                  ------

          Vm(dscf)                    91.86876
          Vm(dscm)                    2.601723
          Vw gas(scf)                 3.210915
          Vw gas (scm)                9.093311E-02
          % moisture                  3.377078
          Md                          .9662292
          MWd                         29.4596
          MW                          29.0726
          Vs(fpm)                     5658.119
          Vs (mpm)                    1725.036
          Flow(acfm)                  26402.94
          Flow(acmm)                  747.7312
          Flow(dscfm)                 20821.67
          Flow(dscmm)                 589.6698
          % I                         109.2916
          % EA                        684.6008



                                            Program Revision:1/16/84
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```
           R A D I A N   S O U R C E   T E S T
           E P A   M E T H O D   2 - 5
           ( R A W   D A T A )
        PLANT                : DIOXIN SITE #03
        PLANT SITE           :
        SAMPLING LOCATION    : UNIT     EXHAUST
        TEST #               : 03-MM5-03
        DATE                 : 11/17/84
        TEST PERIOD          :
0-1556 (0940-1235 / 1237-1242 / 1256-1556)


      PARAMETER                             VALUE
      ---------                             -----

      Sampling time (min.)                   360
      Barometric Pressure (in.Hg)            29.48
      Sampling nozzle diameter (in.)         .12
      Meter Volume (cu.ft.)                  142.921
      Meter Pressure (in.H2O)                .501
      Meter Temperature (F)                  64.53
      Stack dimension (sq.in.)               671.9588
      Stack Static Pressure (in.H2O)        -.9
      Stack Moisture Collected (gm)          149.5
      Absolute stack pressure(in Hg)         29.41382
      Average stack temperature (F)          169.4861
      Percent CO2                            4.98
      Percent O2                             15.62
      Percent N2                             79.4
      Delps Subroutine result                40.53412
      DGM Factor                             .9945
      Pitot Constant                         .84
```

```
                    R A D I A N   S O U R C E   T E S T
                    E P A   M E T H O D S   2 - 5
                    F I N A L   R E S U L T S
                 PLANT               : DIOXIN SITE #03
                 PLANT SITE          :
                 SAMPLING LOCATION   : UNIT     EXHAUST
                 TEST #              : 03-MM5-03
                 DATE                : 11/17/84
                 TEST PERIOD         :
0940-1556 (0940-1235 / 1237-1242 / 1256-1556)


                    PARAMETER                       RESULT
                    ---------                       ------

                    Vm(dscf)                         141.1473
                    Vm(dscm)                         3.997292
                    Vw gas(scf)                      7.048925
                    Vw gas (scm)                     .1996256
                    % moisture                       4.75648
                    Md                               .9524351
                    MWd                              29.4216
                    MW                               28.87833
                    Vs(fpm)                          5992.457
                    Vs (mpm)                         1826.969
                    Flow(acfm)                       27963.09
                    Flow(acmm)                       791.9146
                    Flow(dscfm)                      21961.31
                    Flow(dscmm)                      621.9441
                    % I                              106.1348
                    % EA                             292.4218




                                                  Program Revision:1/16/84
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```
     R A D I A N   S O U R C E   T E S T
     E P A   M E T H O D   2 - 5
     ( R A W   D A T A )
   PLANT                : DIOXIN SITE #03
   PLANT SITE           :
   SAMPLING LOCATION    : UNIT     EXHAUST
   TEST #               : 03-MM5-05
   DATE                 : 11/19/84
   TEST PERIOD          : 0845-1503 (0845-1145 / 1203-1503)

 PARAMETER                                  VALUE
 ---------                                  -----

 Sampling time (min.)                        360
 Barometric Pressure (in.Hg)                 29.72
 Sampling nozzle diameter (in.)              .12
 Meter Volume (cu.ft.)                       120.726
 Meter Pressure (in.H20)                     .36
 Meter Temperature (F)                       52.93
 Stack dimension (sq.in.)                    671.9588
 Stack Static Pressure (in.H20)             -.9
 Stack Moisture Collected (gm)               80.9
 Absolute stack pressure(in Hg)              29.65382
 Average stack temperature (F)               173.1528
 Percent CO2                                 4.89
 Percent O2                                  15.69
 Percent N2                                  79.4
 Delps Subroutine result                     34.33359
 DGM Factor                                  .9945
 Pitot Constant                              .84
```

```
   R A D I A N   S O U R C E   T E S T
   E P A   M E T H O D S   2 - 5
   F I N A L   R E S U L T S
PLANT                : DIOXIN SITE #03
PLANT SITE           :
SAMPLING LOCATION    : UNIT    EXHAUST
TEST #               : 03-MM5-05
DATE                 : 11/19/84
TEST PERIOD          : 0845-1503 (0845-1145 / 1203-1503)

   PARAMETER                RESULT
   ---------                ------

   Vm(dscf)                  122.8727
   Vm(dscm)                  3.479754
   Vw gas(scf)               3.814435
   Vw gas (scm)              .1080248
   % moisture                3.010911
   Md                        .9698909
   MWd                       29.4044
   MW                        29.06102
   Vs(fpm)                   5039.289
   Vs (mpm)                  1536.369
   Flow(acfm)                23515.24
   Flow(acmm)                665.9516
   Flow(dscfm)               18850.24
   Flow(dscmm)               533.8387
   % I                       107.642
   % EA                      297.6326




                                        Program Revision:1/16/84
```

APPENDIX A-2
CONTINUOUS EMISSION MONITORING RESULTS

CEM RESULTS - SITE 03 - TEST 1

TIME	O2 (%V)	CO (PPMV)	CO2 (%V)	NOX (PPMV)	THC (PPMV)
1005	13.3	5561.5	18.9		5.8
1010	13.5	5203.4	23.5		8.2
1015	13.5	5585.0	21.7		6.3
1020	13.6	5594.4	22.6		5.9
1025	13.8	5640.8	21.8	799.3	5.2
1030	13.9	6176.5	20.2	803.0	5.7
1035	13.9	6490.1	22.8	825.1	5.5
1040	14.1	6610.9	22.9	828.9	5.8
1045	14.4	7039.4	23.2	825.0	5.3
1050	15.2	6798.1	20.9	810.2	10.5
1055	15.6	6002.3	21.0	786.9	20.4
1100	15.1	5744.4	17.8	727.2	19.9
1105	15.1	5483.8	17.5	726.8	19.5
1110	14.5	5346.8	21.9	641.8	17.5
1115	15.0	5722.5	23.2	763.2	18.7
1120	14.8	6071.2	20.6	750.4	20.2
1125	14.7	5618.7	18.7	743.8	20.4
1130	14.7	6378.3	17.9	727.6	17.5
1135	14.6	6607.8	22.2	757.4	16.9
1140	14.4	6419.7	19.7	712.0	18.1
1145	14.6	6219.9	22.0	766.1	18.6
1200	14.3	6497.1	21.0	853.0	
1205	14.3	6673.4	21.3	804.1	
1210	14.4	7059.4	20.4	855.3	
1215	14.4	7022.6	21.8	848.7	
1220	14.5	7153.0	20.9	836.0	
1225	14.6	7358.8	20.5	843.5	
1230	14.4	6699.4	19.1	845.0	
1235	14.4	6816.7	17.4	858.3	
1240	14.4	6502.2	22.3	829.1	
1245	14.6	7126.9	21.7	890.4	
1250	14.5	6258.8	19.4	849.2	
1255	14.9	7987.7	19.5	889.9	
1300	14.7	7061.9	18.9	861.5	
1305	14.9	6443.6	20.7	890.3	
1310	14.7	7123.7	17.5	831.9	
1315	14.7	6377.7	20.5	848.0	
1320	14.4	5649.6	19.8	775.9	
1325	14.5	6226.6	18.3	795.9	
1330	14.5	5994.6	21.0	787.4	
1335	14.2	5272.4	16.9	767.2	
1340	14.8	6638.8	19.7	807.2	
1345	14.3	5692.0	16.3	770.4	
1350	14.7	6727.4	18.6	834.5	
1355	14.8	6487.6	18.5	807.9	
NO. PTS.	45	45	45	41	21
MEAN	14.5	6337.0	20.3	804.3	12.9
STD. DEV.	0.5	627.3	1.9	53.2	6.4

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CEM RESULTS - SITE 03 - TEST 3

TIME	O2 (%V)	CO (PPMV)	CO2 (%V)	NOX (PPMV)	THC (PPMV)
945	11.2	1213.2	19.2	677.8	18.9
950	11.3	1960.8	19.6	768.7	10.8
955	11.3	1547.9	19.7	695.2	8.6
1000	11.2	1226.0	18.6	691.9	7.7
1005	11.3	1788.0	16.2	784.8	7.5
1010	11.3	1350.5	18.8	787.2	7.2
1015	11.4	1248.7	15.5	737.7	7.1
1020	10.9	1375.4	17.2	705.1	6.7
1025	10.8	1225.7	14.4	708.9	6.6
1030	11.4	1498.6	16.7	786.0	7.0
1035	11.2	1400.2	14.5	815.2	9.4
1040	11.6	1380.5	14.9	739.9	8.7
1045	12.1	1672.3	21.1	810.0	8.0
1050	12.4	1744.1	17.2	955.9	7.9
1055	11.9	1746.2	18.3	806.6	7.5
1100	12.3	1849.5	22.1	783.1	8.0
1105	11.8	1381.7	17.4	740.6	9.8
1110	11.8	1524.1	15.6	808.5	6.8
1115	11.7	1374.0	17.7	777.4	5.9
1120	11.8	1490.6	18.9	673.4	6.3
1125	12.4	2247.7	16.0	930.9	7.0
1130	11.6	1495.6	15.3	712.3	5.8
1135	12.4	2230.3	18.4	804.1	6.9
1140	11.7	1411.7	17.2	857.3	6.4
1145	12.3	1618.9	18.1	651.5	5.9
1150	12.5	2598.9	18.1	935.7	7.2
1155	11.6	1483.9	15.9	740.0	6.4
1200	12.9	2962.3	17.7	749.9	7.8
1205	12.2	1708.9	18.5	724.5	7.5
1210	11.4	1641.4	17.4	725.6	6.0
1215	11.9	2105.8	16.5	890.2	7.6
1220	11.8	1951.4	17.9	631.9	5.0
1225	11.8	1846.5	18.2	792.8	5.9
1230	11.7	2408.1	14.5	846.6	6.1
1235	12.0	2045.1	17.5	780.7	6.4
1240	11.7	2014.4	16.0	748.1	6.0
1300	11.6	2081.8	16.8	738.7	5.3
1305	12.0	2366.2	18.2	750.7	5.7
1310	11.7	2573.3	15.3	767.7	5.7
1315	11.7	2661.1	16.0	800.0	5.8
1320	11.9	2295.8	16.9	681.2	5.6
1325	11.9	2508.1	17.1	725.0	6.6
1330	11.7	2358.8	19.9	700.3	5.5
1335	11.8	2824.9	20.5	750.0	5.3
1340	11.8	2258.2	15.2	713.7	5.4
1345	11.9	2504.1	18.4	745.2	9.6
1350	11.6	1904.1	14.6	708.5	5.3
1355	11.6	1952.9	15.7	728.7	5.0
1400	11.5	2223.5	17.0	705.8	5.3
1405	11.3	2777.6	17.4	767.7	5.1

CEM RESULTS - SITE 03 - TEST 3

TIME	O2 (%V)	CO (PPMV)	CO2 (%V)	NOX (PPMV)	THC (PPMV)
1410	11.7	1982.6	17.5	673.5	5.4
1415	11.7	2123.5	16.9	687.5	4.8
1420	11.4	2089.6	15.6	726.1	10.8
1425	11.1	1203.9	17.6	635.0	4.7
1430	11.2	1444.0	22.0	687.4	4.6
1435	11.6	1259.9	17.2	823.1	3.8
1440	11.4	1292.4	18.3	770.4	5.8
1445	11.5	1116.5	21.1	694.6	5.7
1450	11.7	1342.5	18.5	790.6	5.7
1455	11.8	1891.5	20.4	906.4	5.1
1500	11.4	878.6	17.9	747.2	5.3
1505	11.7	1484.2	19.1	722.9	4.1
1510	11.5	1662.1	19.1	830.8	5.0
1515	11.4	1234.3	18.6	737.1	4.3
1520	11.8	1191.5	19.4	774.2	5.2
1525	11.3	1078.6	16.4	755.8	4.2
1530	11.6	1334.4	16.6	899.5	6.6
1535	11.4	1114.7	16.4	740.2	3.5
1540	11.3	1062.0	20.9	740.2	3.9
1545	11.9	1076.0	21.5	900.0	4.3
1550	11.4	793.7	20.7	691.0	4.3
1555	11.7	1897.5	16.0	822.5	3.3
NO. PTS.	72	72	72	72	72
MEAN	11.7	1744.6	17.7	761.3	6.4
STD. DEV.	0.4	507.4	1.9	70.3	2.2

CEM RESULTS - SITE 03 - TEST 5

TIME	C2 (%V)	CO (PPMV)	CO2 (%V)	NOX (PPMV)	THC (PPMV)
=======	=======	=======	=======	=======	=======
845.00	18.0	6028.9	19.1	623.9	18.35
850.00	18.2	6540.4	17.4	862.8	18.53
855.00	18.3	6057.2	22.1	866.4	19.65
900.00	18.2	6507.9	16.7	713.7	
905.00	18.3	6192.8	29.8	959.9	22.83
910.00	18.2	5191.9	22.2	723.1	17.79
915.00	18.4	6004.8	16.1	745.3	16.37
920.00	18.5	6652.2	20.1	812.9	21.25
925.00	18.3	5646.1	13.3	782.0	15.97
930.00	18.5	6751.3	13.9	797.9	21.26
935.00	18.2	5074.3	23.3	797.5	27.62
940.00	18.4	3601.4	14.3	820.1	23.45
945.00	18.5	5089.8	14.7	829.6	21.82
950.00	18.3	5534.6	17.9	830.0	20.32
955.00	18.5	5742.8	25.5	805.5	21.53
1000.00	18.3	5510.6	18.1	955.2	29.24
1005.00	18.2	5912.9	22.5	706.2	29.45
1010.00	18.3	5801.0	20.5	822.3	34.93
1015.00	18.5	7301.2	24.4	781.1	32.04
1020.00	18.3	6313.1	17.9	703.4	
1025.00	18.4	5995.5	20.0	851.4	59.60
1030.00	18.3	5971.2	17.2	714.0	33.02
1035.00	18.5	6742.4	16.5	845.2	38.02
1040.00	18.5	6762.0	22.2	833.4	45.10
1045.00	18.4	5658.4	20.2	844.2	
1050.00	18.3	6499.6	20.3	839.9	46.51
1055.00	18.4	5922.4	25.7	904.4	42.36
1100.00	18.5	7660.4	21.6	764.0	41.89
1105.00	18.5	8651.2	17.7	927.1	45.97
1110.00	18.4	5145.3	20.4	779.6	44.12
1115.00	18.7	6234.6	20.0	954.7	35.81
1120.00	18.5	6278.3	16.5	894.1	
1125.00	18.5	6469.0	17.4	845.3	23.22
1130.00	18.8	5224.0	20.7	892.5	39.92
1135.00	18.4	6702.0	20.9	869.6	40.28
1140.00	18.7	5424.1	20.1	801.1	45.22
1145.00	18.5	4702.9	16.9	908.8	39.98
1205.00	18.3	6950.2	15.8	737.5	52.52
1210.00	18.6	6691.1	14.8	727.7	
1215.00	18.4	7486.4	13.7	840.3	61.40
1220.00	18.5	8124.2	18.6	733.9	68.51
1225.00	18.4	5877.9	11.1	692.7	
1230.00	18.5	7517.0	20.3	839.1	68.64
1235.00	18.4	4599.2	15.9	727.9	74.16

CEM RESULTS - SITE 03 - TEST 5

TIME	O2 (%V)	CO (PPMV)	CO2 (%V)	NOX (PPMV)	THC (PPMV)
1240.00	18.4	7540.3	18.5	821.6	
1245.00	18.5	6639.6	17.5	715.8	80.15
1250.00	18.5	6410.9	22.8	829.9	62.12
1255.00	18.6	5295.6	18.5	791.0	72.34
1300.00	18.3	5111.2	11.0	698.9	
1305.00	18.5	6727.2	12.4	767.6	74.18
1310.00	18.8	6904.5	22.8	871.1	64.16
1315.00	18.3	5913.0	13.8	795.6	
1320.00	18.4	6268.4	23.9	784.5	87.21
1325.00	18.4	4915.7	12.3	823.7	59.85
1330.00	18.7	7584.4	24.9	857.4	60.72
1335.00	18.6	5491.1	14.2	817.0	
1340.00	18.4	5113.5	28.0	774.7	56.93
1345.00	18.3	6520.5	14.1	734.8	
1350.00	18.3	6609.1	24.1	769.9	60.05
1355.00	18.2	5348.0	11.1	605.0	64.38
1400.00	18.2	4912.8	28.0	793.9	60.42
1405.00	18.3	5797.2	14.0	755.4	56.01
1410.00	18.2	6374.7	14.0	793.6	46.52
1415.00	18.5	6299.2	21.5	774.9	
1420.00	17.8	3252.6	14.4	746.0	47.44
1425.00	18.4	6983.6	24.6	786.1	46.11
1430.00	18.4	4959.1	15.3	762.6	54.30
1435.00	18.3	2069.0	34.2	766.2	
1440.00	18.2	4668.1	14.6	700.8	58.14
1445.00	18.3	4560.9	15.7	830.6	
1450.00	18.6	5844.3	19.3	891.0	62.18
1455.00	18.3	3575.9	11.9	822.1	52.18
1500.00	18.2	5691.7	16.2	733.8	60.55
NO. PTS.	73	73	73	73	59
MEAN	18.4	5946.9	18.7	798.9	48.82
STD. DEV.	0.2	1095.6	4.7	71.3	18.73

APPENDIX A-3
EPA METHOD 3 FIXED GAS RESULTS

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FIXED GAS ANALYSIS RESULTS FOR SSI-B[a]

Run Number	Sample Number[b]	Fixed Gas Concentrations[c] O_2	CO_2	N_2	Total Percentages[d]
1	1[e]	19.2	3.42	82.2	104.8
	2	17.9	4.66	84.7	106.1
	average	17.9	4.66	84.7	106.1
3	1	15.1	5.43	80.5	101.0
	2	16.1	4.52	77.7	98.3
		15.6	4.98	79.1	99.7
5	1	15.5	4.88	80.2	100.6
	2	15.9	4.90	82.7	103.5
		15.7	4.89	81.4	102.1

[a] Analysis by gas chromatograph/thermal conductivity detector.

[b] Represents Tedlar bags of stack gas collected according to EPA Method 3.

[c] Concentrations presented represent average values from duplicate sample analysis.

[d] Sum of fixed gas concentrations. Difference from 100 percent are due to analytical error.

[e] Leak suspected in bag sampling system for first bag.

[f] First bag sample not included in average.

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APPENDIX A-4

MODIFIED METHOD 5 AND EPA METHODS 1-4 SAMPLE CALCULATIONS

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RADIAN SOURCE TEST
EPA METHOD 2-5
SAMPLE CALCULATION

PLANT : DIOXIN SITE #03
PLANT SITE :
SAMPLING LOCATION : UNIT EXHAUST
TEST # : 03-MM5-01
DATE : 11/15/84
TEST PERIOD : 0946-1358 (0946-1146 / 1158-1358)

) Volume of dry gas sampled at standard conditions (68 deg-F ,29.92 in. Hg).

$$Vm(std) = \frac{Y \times Vm \times [T(std) + 460] \times [Pb + (Pm/13.6)]}{P(std) \times (Tm + 460)}$$

$$Vm(std) = \frac{.9945 \times 90.001 \times 528 \times [\ 29.18 + (\ .445\ /13.6)]}{29.92 \times (\ 42.26 + 460)}$$

$$Vm(std) = 91.869 dscf$$

) Volume of water vapor at standard conditions:

$$Vw(gas) = 0.04715\ cf/gm \times W(l)\ gm$$

$$Vw(gas) = 0.04715 \times 68.1 = 3.211\ scf$$

) Percent Moisture in stack gas :

$$\%M = \frac{100 \times Vw(gas)}{Vm(std) + Vw(gas)}$$

$$\%M = \frac{100 \times 3.211}{91.869 + 3.211} = 3.38\ \%$$

4) Mole fraction of dry stack gas :

$$Md = \frac{100 - \%M}{100} = \frac{100 - 3.38}{100} = .9662292$$

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SAMPLE CALCULATION
PAGE TWO

5)Average Molecular Weight of DRY stack gas :

MWd = (.44 x %CO2) + (.32 x %O2) + (.28 x %N2)

MWd = (.44 x 4.66) + (.32 x 17.85) + (.28 x 77.49) = 29.4596

6)Average Molecular Weight of wet stack gas :

MW = MWd x Md + 18(1 - Md)

MW = 29.4596 x .9662292 + 18(1 - .9662292) = 29.0726

7) Stack gas velocity in feet-per-minute (fpm) at stack conditions :

Vs = KpxCp x [SQRT (dP)]§avet x SQRT [Ts §avgt] x SQRT [1/(PsxMW)] x 60sec/min

Vs = 85.49 x .84 x 60 x 38.20479 x SQRT[1/(29.11382 X 29.0726)]

Vs = 5658.119 FPM

8) Average stack gas dry volumetric flow rate (DSCFM) :

$$Qsd = \frac{Vs \times As \times Md \times T(std) \times Ps}{144\ cu.in./cu.ft. \times (Ts + 460) \times P(std)}$$

$$Qsd = \frac{5658.119 \times 671.9588 \times .9662292 \times 528 \times 29.11382}{144 \times 629.4894 \times 29.92}$$

Qsd = 20821.67 dscfm

```
                 S A M P L E   C A L C U L A T I O N
                 P A G E   T H R E E

9)Isokinetic sampling rate (%) :

        Dimensional Constant C = K4 x 60 x 144 x [1 / (Pi  /4)]
        K4 = .0945 FOR ENGLISH UNITS

                        C x Vm(std) x (Ts + 460)
        I% =      -------------------------------------
                  Vs x Tt x Ps x Md x (Dn)°2

                     1039.574 x 91.86876 x 629.4894
        I% = -------------------------------------------
               5658.119 x 240 x 29.11382 x .9662292 x( .12 )°2

        I% =   109.2916

10) Excess air (%) :

                  100 x %02             100 x 17.85
        EA =   --------------- = ---------------
               (.264 x %N2) - %02  (.264 x 77.49 ) - 17.85

        EA =        684.60

11) Particulate Concentration :

        Cs = ( grams part.) / Vm(std) =  0 / 91.86876

        Cs =        0.0000000 Grams/DSCF

                  T(std) x Md x Ps x Cs
        Ca =      ------------------------------
                  P(std) x Ts

                  528 x .9662292  x 29.11382  x       0.0000000
        Ca =      ------------------------------
                  29.92        x       629.4894

        Ca =              0.0000000 Grams/ACF

        LBS/HR =  Cs x 0.002205 x Qsd x 60

        LBS/HR =          0.0000000x 0.002205 x 20821.7 x 60

        LBS/HR = 0

                                              Program Revision:1/16/84
```

RADIAN SOURCE TEST
EPA METHODS 2-5
DEFINITION OF TERMS

PARAMETER	DEFINITION
Tt(min.)	TOTAL SAMPLING TIME
Dn(in.)	SAMPLING NOZZLE DIAMETER
Ps(in.H2O)	ABSOLUTE STACK STATIC GAS PRESSURE
Vm(cu.ft.)	ABSOLUTE VOLUME OF GAS SAMPLE MEASURED BY DGM
Vw(gm.)	TOTAL STACK MOISTURE COLLECTED
Pm(In.H2O)	AVERAGE STATIC PRESSURE OF DGM
Tm(F)	AVERAGE TEMPERATURE OF DGM
Pb(In.Hg.)	BAROMETRIC PRESSURE
% CO2	CARBON DIOXIDE CONTENT OF STACK GAS
% O2	OXYGEN CONTENT OF STACK GAS
% N2	NITROGEN CONTENT OF STACK GAS
SQR(DELPS)	AVE. SQ. ROOT OF S-PITOT DIFF. PRESSURE-TEMP. PRODUCTS
As(sq.in.)	CROSS-SECTIONAL AREA OF STACK(DUCT)
Ts(F)	TEMPERATURE OF STACK
Vm(dscf)	STANDARD VOLUME OF GAS SAMPLED ,Vm(std),AS DRY STD. CF
Vm(dscm)	STANDARD VOLUME OF GAS SAMPLED,Vm(std),AS DRY STD. CM
Vw gas(scf)	VOLUME OF WATER VAPOR IN GAS SAMPLE,STD
% moisture	WATER VAPOR COMPOSITION OF STACK GAS
Md	PROPORTION, BY VOLUME,OF DRY GAS IN GAS SAMPLE
MWd	MOLECULAR WEIGHT OF STACK GAS,DRY BASIS LB/LB-MOLE
MW	MOLECULAR WEIGHT OF STACK GAS,WET BASIC LB/LB-MOLE
Vs(fpm)	AVERAGE STACK GAS VELOCITY
Flow(acfm)	AVERAGE STACK GAS FLOW RATE(ACTUAL STACK COND.)
Flow(acmm)	AVERAGE STACK GAS FLOW RATE(ACTUAL STACK COND.)
Flow(dscfm)	AVERAGE STACK GAS VOLUMETRIC FLOW RATE(DRY BASIS)
Flow(dscmm)	AVERAGE STACK GAS VOLUMETRIC FLOW RATE(DRY BASIS)
% I	PERCENT ISOKINETIC
% EA	PERCENT EXCESS AIR IN STACK GAS
DGM	DRY GAS METER
Y	DRY GAS METER CORRECTION FACTOR
Pg	STACK STATIC GAS PRESSURE
Cp	PITOT COEFFICIENT
dH	ORIFICE PLATE DIFF. PRESS. VALUE
dP	PITOT DIFF. PRESS. VALUE
*** EPA STANDARD CONDITIONS	Temperature = 68 deg-F (528 deg-R) Pressure = 29.92 in. Hg.

APPENDIX B
PROCESS DATA SUMMARY

APPENDIX B
PROCESS DATA TABLE

Definition of Terms

FEED RATE = sludge feed rate to incinerator, wet basis, ton/hr
ID INLET = induced draft fan inlet temperature, °F
STEAM PROD = waste heat boiler steam production, lb/hr
VENTURI H_2O FLOW = venturi scrubber water flow, gpm
VENTURI DP = venturi scrubber pressure drop, in. H_2O
SUBCOOLER DP = subcooler pressure drop, in. H_2O
SUBCOOLER H_2O FLOW = subcooler water flow, gpm
SUBCOOLER TEMP = subcooler gas outlet temperature, °F
CYCLONE DP = cyclone pressure drop, in. H_2O
VENTURI TEMP = venturi scrubber gas outlet temperature, °F
SCRUBBER H_2O FLOW = total water flow to venturi scrubber plus subcooler, gpm

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DATE	TIME	FEED RATE	ID INLET	STEAM PROD	VENTURI H2O FLOW	VENTURI DP	SUBCOOLR TEMP	SUBCOOLR H2O FLOW	SUBCOOLR DP	CYCLONE DP	VENTURI TEMP	SCRUBBER H2O FLOW
111584	800	.	135	8800	190	24	68	980	4.5	3.8	140	1170
111584	900	7	140	8200	190	25	68	980	3.5	3.6	140	1170
111584	1000	7.4	140	9100	190	24	68	980	4	3.4	140	1170
111584	1100	7.1	135	9600	190	25	68	980	5	3.2	140	1170
111584	1200	8.1	135	9400	190	25	70	980	5.75	4.2	140	1170
111584	1300	7	135	12160	190	25	70	980	5	4.2	140	1170
111584	1400	6.7	135	8200	0	.	.	0	.	.	140	0
111584	1500	7.3	135	10120	190	25	70	980	4	4	140	1170
111584	1600	7.9	135	.	190	25	70	980	3.5	4	140	1170
111584	1700	7.8	135	9560	190	25	70	980	5	3.5	140	1170
111584	1800	7.7	135	9000	190	25	70	980	4.5	4	140	1170
111584	1900	7.1	135	.	190	25	70	980	5	2.5	140	1170
111584	2000	7.5	135	10080	190	25	70	980	5.5	3	140	1170
111584	2100	6.2	135	9520	190	25	70	980	5	3	135	1170
111584	2200	6.4	135	8800	190	25	69	980	4.5	2.5	140	1170
111584	2300	6.1	140	9200	190	25	70	980	4.5	2.5	140	1170
111584	2400	6.4	140	7400	190	25	70	980	4.5	2	140	1170
111584	100	7.3	135	6200	190	25	70	980	4.5	2.4	140	1170
111584	200	6.9	140	10800	190	25	70	980	5	1.5	140	1170
111584	300	6.9	135	8000	190	25	69	980	5	1.8	140	1170
111584	400	7.2	135	8600	190	25	69	980	4.5	2	140	1170
111584	500	7.9	135	9600	190	25	70	980	4.5	2	140	1170
111584	600	7.8	135	11400	190	25	70	980	5	2.4	140	1170
111584	700	6.6	130	10600	180	25	70	1000	5	2.4	140	1180
111584	800	8.1	130	9200	180	25	70	1000	5	2.4	140	1180
111784	800	8.9	135	14960	180	27	74	960	6	7.6	150	1140
111784	900	9	135	15160	190	26	74	1000	5.5	7.2	150	1190
111784	1000	8.9	135	14080	185	25	74	1000	6	8	150	1185
111784	1100	8.4	135	14600	180	25	74	1000	6	7.6	150	1180
111784	1200	8.5	135	14520	180	25	74	1000	6	7	150	1180
111784	1300	9.1	130	14000	180	25	74	1000	6	7.6	150	1180
111784	1400	9	130	13080	190	26	76	1000	6	7.6	150	1190
111784	1500	9	130	13560	190	26	76	1000	6	7.4	150	1190
111784	1600	8.4	130	14040	190	26	76	1000	6	7.4	150	1190
111784	1700	7.9	135	13360	190	26	76	1000	6	7.2	150	1190
111784	1800	8.5	135	13280	190	25	74	1000	6	7.4	150	1190
111784	1900	9.1	135	12360	180	26	76	1000	6	7.4	150	1180
111784	2000	8.1	135	12400	190	30	76	1000	7	7.4	125	1190
111784	2100	8.9	135	13200	190	20	65	1000	2	6.8	125	1190
111784	2200	5.3	135	12000	190	20	65	1000	6	1.4	150	1190
111784	2300	9	135	8400	180	32	75	1000	7	1.8	150	1180
111784	2400	8.8	135	13600	180	32	72	1000	5.5	1.8	150	1180
111784	100	8.5	140	11600	190	32	75	1000	5.5	1.8	150	1190
111784	200	8.7	135	14000	190	32	76	1000	7	6.8	150	1190
111784	300	9.4	140	12000	190	32	76	1000	7	7	150	1190
111784	400	7.7	140	15000	190	32	76	1000	7	7	150	1190
111784	500	6.7	135	12800	190	27	72	960	6.5	.	140	1150
111784	600	7.9	135	12400	0	.	.	0	.	.	.	0
111784	700	0	135	11400	190	25	70	980	6	4.2	140	1170
111784	800	.	.	.	190	25	70	980	6	4.4	140	1170
11884	800	7.6	130	11040	190	25	70	980	6	4.4	140	1170
84	900	7.8	130	9960	190	27	74	980	7	4.2	150	1170
	1000	7.8	130	11080	190	28	79	980	7	4	150	1170

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111884	1100	7.6	135	14200	190	25	70	980	6	3	140	1170
111984	800	6.9	130	11500	190	24	68	960	3.5	2	130	1150
111984	900	9	130	11500	190	25	68	960	3.4	2	130	1150
111984	1000	4.8	130	10120	0	.	.	0	.	.	.	0
111984	1100	6.7	130	9200	0	.	.	0	.	.	.	0
111984	1200	6.6	130	10040	190	25	68	960	4.5	3.2	140	1150
111984	1300	7.2	130	9440	190	25	68	960	4.5	3.2	140	1150
111984	1400	7	130	9360	190	25	68	960	4	3.4	140	1150
111984	1500	6.9	135	10600	190	25	68	960	4	2.5	140	1150
111984	1600	7.2	135	7720	190	25	68	860	4.5	3	135	1050
111984	1700	7.9	130	10000	190	25	68	960	4.5	2.5	135	1150
111984	1800	7.6	130	10440	190	25	68	1000	5	3	135	1190
111984	1900	7.2	140	10520	190	25	68	1000	4.5	3	135	1190
111984	2000	6.7	140	8080	190	25	65	1000	3	2.5	130	1190
111984	2100	7.7	130	8080	190	25	68	1000	4.5	2	135	1190
111984	2200	7.8	130	11200	190	25	68	1000	5	3	140	1190
111984	2300	7.2	130	10400	190	25	68	1000	5	1.8	140	1190
111984	2400	7.2	130	10800	190	25	68	1000	5	2	140	1190
111984	100	7.8	130	11600	190	25	70	1000	5	2.8	140	1190
111984	200	7.8	130	10800	190	25	70	1000	5	2.6	140	1190
111984	300	7.2	130	9200	190	25	70	1000	4.5	3	140	1190
111984	400	7.7	130	11200	190	25	70	1000	4.5	2.8	140	1190
111984	500	7	130	8200	190	25	70	1000	4.5	3	140	1190
111984	600	6.4	130	11200	190	25	70	1000	4.5	2.6	140	1190
111984	700	6.1	135	10120	190	25	64	960	3	0	130	1150
111984	800	6.6	135	8440	190	25	64	960	3.5	0	130	1150

APPENDIX C
SAMPLE SHIPMENT LETTER

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ADIAN
orporation

November 19, 1984

. S. EPA Toxicant Analysis Center
uilding 1105
ay St. Louis, MS 39529

ttention: Danny McDaniel

ubject: Tier 4 - Analysis Instructions

ear Sir:

The objective of this letter is to clarify instructions and priorities for individual samples from specific Tier 4 combustion sites. his instruction letter is No. 3 and pertains to EPA Site No. 03.

The episode No. is 2494, and SCC numbers assigned to this site were umbers DQ000301 through DQ000324.

SCC numbers DQ000301 through DQ000306 have been assigned to Troika or internal QA/QC purposes. Number DQ000324 was not used and all emaining numbers have been assigned to samples as described below.

The sample shipment for EPA Site No. 03 consists of 4 boxes ontaining samples.

Instructions for extraction and analysis follow.

. The following samples require IMMEDIATE EXTRACTION and analysis (Priority #1 samples).

Radian Run # 03-MM5-01
(Total of 6 train components)

SCC #	Container	Fraction
DQ000311	1	Filter
DQ000311	6	XAD Module
DQ000311	2	Probe Rinse
DQ000311	3	Back Half / Coil Rinse
DQ000311	4	Condensate
DQ000311	5	Impinger Solution

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Radian Run # 03-MM5-03
(Total of 6 train components)

SCC #	Container	Fraction
DQ000308	1	Filter
DQ000308	6	XAD Module
DQ000308	2	Probe Rinse
DQ000308	3	Back Half / Coil Rinse
DQ000308	4	Condensate
DQ000308	5	Impinger Solution

Radian Run # 03-MM5-Blank
(Total of 6 train components)

SCC #	Container	Fraction
DQ000312	1	Filter
DQ000312	6	XAD Module
DQ000312	2	Probe Rinse
DQ000312	3	Back Half / Coil Rinse
DQ000312	4	Condensate
DQ000312	5	Impinger Solution

Radian Run # 03-MM5-04
(Total of 6 train components)

SCC #	Container	Fraction
DQ000318	1	Filter
DQ000318	6	XAD Module
DQ000318	2	Probe Rinse
DQ000318	3	Back Half / Coil Rinse
DQ000318	4	Condensate
DQ000318	5	Impinger Solution

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Bottom Ash - Process Sample

SCC #	Sample
DQ000309	Ash
DQ000317	Ash
DQ000322	Ash

Scrubber Blowdown Solids - Process Sample

SCC #	Sample
DQ000315	Scrubber blowdown solids
DQ000316	Scrubber blowdown solids
DQ000321	Scrubber blowdown solids

Scrubber Blowdown Filtrate - Process Sample

SCC #	Sample
DQ000313	Scrubber blowdown filtrate
DQ000314	Scrubber blowdown filtrate
DQ000320	Scrubber blowdown filtrate

The following Priority #2 samples for this site should be held for analysis pending the results of Priority #1 analyses:

SCC #	Sample
DQ000307	Sewage sludge feed
DQ000310	Sewage sludge feed
DQ000319	Sewage sludge feed

The soil sample is the only Priority #3 sample. It will be held at Radian for analysis pending the results of Priority #1 and Priority #2 samples. The SCC number for the soil sample is DQ000323.

If there are any questions concerning this sample shipment, please
tact either Dave Savia, Mike Palazzolo, or Andrew Miles at Radian
poration (919) 541-9100.

Sincerely,

Mike Palazzolo

TEST TEAM LEADER

APPENDIX D

DIOXIN/FURAN ANALYTICAL DATA FOR GASEOUS SAMPLES

TABLE D-1. DIOXIN/FURAN ANALYTICAL DATA FOR MM5 TRAINS - SITE SSI-B

Isomer/ Homologue	Amount Detected, Picograms per Sample Train (Detection limit)		
	Run 01	Run 03	Run 05
Dioxins			
2378 TCDD	ND (30.0)	ND (240)	ND (40)
Other TCDD	500	ND (240)	100
Penta CDD	ND (50.0)	ND (180)	ND (200)
Hexa CDD	ND (480)	ND (410)	ND (30)
Hepta CDD	300	ND (270)	ND (140)
Octa CDD	800	700	600
Total PCDD	1,600	700	700
Furans			
2378 TCDF	1,900	1,000	1,400
Other TCDF	19,500	6,100	9,300
Penta CDF	5,400	ND (180)	2,500
Hexa CDF	2,200	ND (230)	ND (740)
Hepta CDF	ND (620)	ND (290)	ND (70)
Octa CDF	100	ND (50)	ND (60)
Total PCDF	29,100	7,100	13,200

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[a] Spiked at 5 ng in each sample.

[b] Spiked at 20 ng in each sample.

[c] ND = not detected. Detection limit ranged from 0.01 to 0.19 ng.

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APPENDIX E
RUN-SPECIFIC DIOXIN/FURAN EMISSIONS DATA

APPENDIX E-1

RUN-SPECIFIC DIOXIN/FURAN EMISSIONS DATA

(As-Measured Concentrations)

TABLE E-1. DIOXIN/FURAN EMISSIONS DATA FOR RUN 1, SITE SSI-B

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Concentration In Flue Gas (ppt)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	ND (1.15E-02)	ND (8.62E-04)	ND (4.08E-01)
Other TCDD	1.92E-01(N/A)	1.44E-02(N/A)	6.80E+00
Penta-CDD	ND (1.92E-02)	ND (1.30E-03)	ND (6.80E-01)
Hexa-CDD	ND (1.85E-01)	ND (1.14E-02)	ND (6.53E+00)
Hepta-CDD	1.15E-01(N/A)	6.53E-03(N/A)	4.08E+00
Octa-CDD	3.08E-01(N/A)	1.61E-02(N/A)	1.09E+01
Total PCDD	6.15E-01	3.70E-02	2.18E+01
FURANS			
2378 TCDF	7.31E-01(N/A)	5.74E-02(N/A)	2.59E+01
Other TCDF	7.50E+00(N/A)	5.90E-01(N/A)	2.65E+02
Penta-CDF	2.08E+00(N/A)	1.47E-01(N/A)	7.35E+01
Hexa-CDF	8.46E-01(N/A)	5.43E-02(N/A)	2.99E+01
Hepta-CDF	ND (2.38E-01)	ND (1.40E-02)	ND (8.44E+00)
Octa-CDF	3.85E-02(N/A)	2.08E-03(N/A)	1.36E+00
Total PCDF	1.12E+01	8.50E-01	3.96E+02

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = Not detected (detection limit in parentheses).
N/A = Not applicable. QA samples indicate the method capabilities and minimum limits of detection values when values are positive.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
8760 operating hours per year

TABLE E-2. DIOXIN/FURAN EMISSIONS DATA FOR RUN 3, SITE SSI-B

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Concentration In Flue Gas (ppt)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	ND (6.00E-02)	ND (4.48E-03)	ND (2.24E+00)
Other TCDD	ND (6.00E-02)	ND (4.48E-03)	ND (2.24E+00)
Penta-CDD	ND (4.50E-02)	ND (3.04E-03)	ND (1.68E+00)
Hexa-CDD	ND (1.02E-01)	ND (6.31E-03)	ND (3.82E+00)
Hepta-CDD	ND (6.75E-02)	ND (3.82E-03)	ND (2.52E+00)
Octa-CDD	1.75E-01(N/A)	9.15E-03(N/A)	6.53E+00
Total PCDD	1.75E-01	9.15E-03	6.53E+00
FURANS			
2378 TCDF	2.50E-01(N/A)	1.97E-02(N/A)	9.33E+00
Other TCDF	1.52E+00(N/A)	1.20E-01(N/A)	5.69E+01
Penta-CDF	ND (4.50E-02)	ND (3.18E-03)	ND (1.68E+00)
Hexa-CDF	ND (5.75E-02)	ND (3.69E-03)	ND (2.15E+00)
Hepta-CDF	ND (7.25E-02)	ND (4.26E-03)	ND (2.71E+00)
Octa-CDF	ND (1.25E-02)	ND (6.77E-04)	ND (4.66E-01)
Total PCDF	1.77E+00	1.40E-01	6.62E+01

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = Not detected (detection limit in parentheses).
N/A = Not applicable. QA samples indicate the method capabilities and minimum limits of detection values when values are positive.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
8760 operating hours per year

TABLE E-3. DIOXIN/FURAN EMISSIONS DATA FOR RUN 5 , SITE SSI-B

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Concentration In Flue Gas (ppt)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	ND (1.15E-02)	ND (8.59E-04)	ND (3.68E-01)
Other TCDD	2.87E-02(N/A)	2.15E-03(N/A)	9.20E-01
Penta-CDD	ND (5.75E-02)	ND (3.88E-03)	ND (1.84E+00)
Hexa-CDD	ND (8.62E-03)	ND (5.30E-04)	ND (2.76E-01)
Hepta-CDD	ND (4.02E-02)	ND (2.28E-03)	ND (1.29E+00)
Octa-CDD	1.72E-01(N/A)	9.02E-03(N/A)	5.52E+00
Total PCDD	2.01E-01	1.12E-02	6.44E+00
FURANS			
2378 TCDF	4.02E-01(N/A)	3.16E-02(N/A)	1.29E+01
Other TCDF	2.67E+00(N/A)	2.10E-01(N/A)	8.56E+01
Penta-CDF	7.18E-01(N/A)	5.08E-02(N/A)	2.30E+01
Hexa-CDF	ND (2.13E-01)	ND (1.36E-02)	ND (6.81E+00)
Hepta-CDF	ND (2.01E-02)	ND (1.18E-03)	ND (6.44E-01)
Octa-CDF	ND (1.72E-02)	ND (9.34E-04)	ND (5.52E-01)
Total PCDF	3.79E+00	2.93E-01	1.21E+02

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = Not detected (detection limit in parentheses).
N/A = Not applicable. QA samples indicate the method capabilities and minimum limits of detection values when values are positive.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
8760 operating hours per year

APPENDIX E-2

RUN-SPECIFIC DIOXIN/FURAN EMISSIONS DATA

(Corrected to 3% Oxygen)

TABLE E-4. DIOXIN/FURAN EMISSIONS DATA FOR RUN 1 SITE SSI-B
Concentrations Corrected to 3% Oxygen

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm @ 3% oxygen)	Isomer Concentration In Flue Gas (ppt @ 3% oxygen)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	ND (6.59E-02)	ND (4.93E-03)	ND (4.08E-01)
Other TCDD	1.10E+00(N/A)	8.21E-02(N/A)	6.80E+00
Penta-CDD	ND (1.10E-01)	ND (7.43E-03)	ND (6.80E-01)
Hexa-CDD	ND (1.05E+00)	ND (6.49E-02)	ND (6.53E+00)
Hepta-CDD	6.59E-01(N/A)	3.73E-02(N/A)	4.08E+00
Octa-CDD	1.76E+00(N/A)	9.19E-02(N/A)	1.09E+01
Total PCDD	3.52E+00	2.11E-01	2.18E+01
FURANS			
2378 TCDF	4.18E+00(N/A)	3.28E-01(N/A)	2.59E+01
Other TCDF	4.29E+01(N/A)	3.37E+00(N/A)	2.65E+02
Penta-CDF	1.19E+01(N/A)	8.40E-01(N/A)	7.35E+01
Hexa-CDF	4.84E+00(N/A)	3.10E-01(N/A)	2.99E+01
Hepta-CDF	ND (1.36E+00)	ND (8.01E-02)	ND (8.44E+00)
Octa-CDF	2.20E-01(N/A)	1.19E-02(N/A)	1.36E+00
Total PCDF	6.40E+01	4.86E+00	3.96E+02

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = Not detected (detection limit in parentheses).
N/A = Not applicable. QA samples indicate the method capabilities and minimum limits of detection values when values are positive.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
8760 operating hours per year

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TABLE E-5. DIOXIN/FURAN EMISSIONS DATA FOR RUN 3 , SITE SSI-B
Concentrations Corrected to 3% Oxygen

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm @ 3% oxygen)	Isomer Concentration In Flue Gas (ppt @ 3% oxygen)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	ND (2.01E-01)	ND (1.50E-02)	ND (2.24E+00)
Other TCDD	ND (2.01E-01)	ND (1.50E-02)	ND (2.24E+00)
Penta-CDD	ND (1.51E-01)	ND (1.02E-02)	ND (1.68E+00)
Hexa-CDD	ND (3.43E-01)	ND (2.11E-02)	ND (3.82E+00)
Hepta-CDD	ND (2.26E-01)	ND (1.28E-02)	ND (2.52E+00)
Octa-CDD	5.86E-01(N/A)	3.06E-02(N/A)	6.53E+00
Total PCDD	5.86E-01	3.06E-02	6.53E+00
FURANS			
2378 TCDF	8.36E-01(N/A)	6.58E-02(N/A)	9.33E+00
Other TCDF	5.10E+00(N/A)	4.01E-01(N/A)	5.69E+01
Penta-CDF	ND (1.51E-01)	ND (1.07E-02)	ND (1.68E+00)
Hexa-CDF	ND (1.92E-01)	ND (1.23E-02)	ND (2.15E+00)
Hepta-CDF	ND (2.43E-01)	ND (1.43E-02)	ND (2.71E+00)
Octa-CDF	ND (4.18E-02)	ND (2.27E-03)	ND (4.66E-01)
Total PCDF	5.94E+00	4.67E-01	6.62E+01

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = Not detected (detection limit in parentheses).
N/A = Not applicable. QA samples indicate the method capabilities and minimum limits of detection values when values are positive.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
8760 operating hours per year

TABLE E-6. DIOXIN/FURAN EMISSIONS DATA FOR RUN 5, SITE SSI-B
Concentrations Corrected to 3% Oxygen

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm @ 3% oxygen)	Isomer Concentration In Flue Gas (ppt @ 3% oxygen)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	ND (3.90E-02)	ND (2.91E-03)	ND (3.68E-01)
Other TCDD	9.74E-02(N/A)	7.28E-03(N/A)	9.20E-01
Penta-CDD	ND (1.95E-01)	ND (1.32E-02)	ND (1.84E+00)
Hexa-CDD	ND (2.92E-02)	ND (1.80E-03)	ND (2.76E-01)
Hepta-CDD	ND (1.36E-01)	ND (7.72E-03)	ND (1.29E+00)
Octa-CDD	5.84E-01(N/A)	3.06E-02(N/A)	5.52E+00
Total PCDD	6.82E-01	3.78E-02	6.44E+00
FURANS			
2378 TCDF	1.36E+00(N/A)	1.07E-01(N/A)	1.29E+01
Other TCDF	9.06E+00(N/A)	7.12E-01(N/A)	8.56E+01
Penta-CDF	2.44E+00(N/A)	1.72E-01(N/A)	2.30E+01
Hexa-CDF	ND (7.21E-01)	ND (4.62E-02)	ND (6.81E+00)
Hepta-CDF	ND (6.82E-02)	ND (4.01E-03)	ND (6.44E-01)
Octa-CDF	ND (5.84E-02)	ND (3.17E-03)	ND (5.52E-01)
Total PCDF	1.29E+01	9.92E-01	1.21E+02

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = Not detected (detection limit in parentheses).
N/A = Not applicable. QA samples indicate the method capabilities and minimum limits of detection values when values are positive.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
8760 operating hours per year

APPENDIX F
RUN-SPECIFIC RISK MODELING INPUT DATA

TABLE F-1. RISK MODELING PARAMETERS FOR RUN 1, SITE SSI-B

Stack Height (From Grade Level) = 27
Stack Diameter (ID) = 0.74
Flue Gas Flow Rate (Dry Standard) = 590
Flue Gas Exit Temperature = 349
Flue Gas Exit Velocity (Actual) = 1725

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Hourly Emissions Rate (ug/hr)	Relative Potency Factor	2,3,7,8 - TCDD Equivalent Emissions (mg/yr)
2378 TCDD	ND (1.15E-02)	ND (4.08E-01)	1.000	ND (3.58E+00)
Other TCDD	1.92E-01	6.80E+00	.010	5.96E-01
2378 TCDF	7.31E-01	2.59E+01	.100	2.26E+01
Other TCDF	7.50E+00	2.65E+02	.001	2.32E+00
Penta-CDD	ND (1.92E-02)	ND (6.80E-01)	.500	ND (2.98E+00)
Penta-CDF	2.08E+00	7.35E+01	.100	6.44E+01
Hexa-CDD	ND (1.85E-01)	ND (6.53E+00)	.040	ND (2.29E+00)
Hexa-CDF	8.46E-01	2.99E+01	.010	2.62E+00
Hepta-CDD	1.15E-01	4.08E+00	.001	3.58E-02
Hepta-CDF	ND (2.38E-01)	ND (8.44E+00)	.001	ND (7.39E-02)
Octa-CDD	3.08E-01	1.09E+01	.000	.00E+00
Octa-CDF	3.85E-02	1.36E+00	.000	.00E+00
Net 2378 TCDD Equivalent Atmospheric Loading				9.26E+01

ND = not detected (detection limit in parentheses).
N/A = detection limit not available
ng = 1.0E-09g
ug = 1.0E-06g
mg = 1.0E-03g
Standard conditions: 293 K (20 C) temperature and 1 atmosphere pressure.
8760 operating hours per year

TABLE F-2. RISK MODELING PARAMETERS FOR RUN 3, SITE SSI-B

Stack Height (From Grade Level) = 27
Stack Diameter (ID) = 0.74
Flue Gas Flow Rate (Dry Standard) = 622
Flue Gas Exit Temperature = 349
Flue Gas Exit Velocity (Actual) = 1827

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Hourly Emissions Rate (ug/hr)	Relative Potency Factor	2,3,7,8 - TCDD Equivalent Emissions (mg/yr)
2378 TCDD	ND (6.00E-02)	ND (2.24E+00)	1.000	ND (1.96E+01)
Other TCDD	ND (6.00E-02)	ND (2.24E+00)	.010	ND (1.96E-01)
2378 TCDF	2.50E-01	9.33E+00	.100	8.17E+00
Other TCDF	1.52E+00	5.69E+01	.001	4.99E-01
Penta-CDD	ND (4.50E-02)	ND (1.68E+00)	.500	ND (7.36E+00)
Penta-CDF	ND (4.50E-02)	ND (1.68E+00)	.100	ND (1.47E+00)
Hexa-CDD	ND (1.02E-01)	ND (3.82E+00)	.040	ND (1.34E+00)
Hexa-CDF	ND (5.75E-02)	ND (2.15E+00)	.010	ND (1.88E-01)
Hepta-CDD	ND (6.75E-02)	ND (2.52E+00)	.001	ND (2.21E-02)
Hepta-CDF	ND (7.25E-02)	ND (2.71E+00)	.001	ND (2.37E-02)
Octa-CDD	1.75E-01	6.53E+00	.000	.00E+00
Octa-CDF	ND (1.25E-02)	ND (4.66E-01)	.000	ND (.00E+00)
Net 2378 TCDD Equivalent Atmospheric Loading				8.67E+00

ND = not detected (detection limit in parentheses).
N/A = detection limit not available
ng = 1.0E-09g
ug = 1.0E-06g
mg = 1.0E-03g
Standard conditions: 293 K (20 C) temperature and 1 atmosphere pressure.
8760 operating hours per year

TABLE F-3. RISK MODELING PARAMETERS FOR RUN 5 , SITE SSI-B

Stack Height (From Grade Level) = 27
Stack Diameter (ID) = 0.74
Flue Gas Flow Rate (Dry Standard) = 534
Flue Gas Exit Temperature = 351
Flue Gas Exit Velocity (Actual) = 1536

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Hourly Emissions Rate (ug/hr)	Relative Potency Factor	2,3,7,8 - TCDD Equivalent Emissions (mg/yr)
2378 TCDD	ND (1.15E-02)	ND (3.68E-01)	1.000	ND (3.23E+00)
Other TCDD	2.87E-02	9.20E-01	.010	8.06E-02
2378 TCDF	4.02E-01	1.29E+01	.100	1.13E+01
Other TCDF	2.67E+00	8.56E+01	.001	7.50E-01
Penta-CDD	ND (5.75E-02)	ND (1.84E+00)	.500	ND (8.06E+00)
Penta-CDF	7.18E-01	2.30E+01	.100	2.02E+01
Hexa-CDD	ND (8.62E-03)	ND (2.76E-01)	.040	ND (9.68E-02)
Hexa-CDF	ND (2.13E-01)	ND (6.81E+00)	.010	ND (5.97E-01)
Hepta-CDD	ND (4.02E-02)	ND (1.29E+00)	.001	ND (1.13E-02)
Hepta-CDF	ND (2.01E-02)	ND (6.44E-01)	.001	ND (5.64E-03)
Octa-CDD	1.72E-01	5.52E+00	.000	.00E+00
Octa-CDF	ND (1.72E-02)	ND (5.52E-01)	.000	ND (.00E+00)
Net 2378 TCDD Equivalent Atmospheric Loading				3.23E+01

ND = not detected (detection limit in parentheses).
N/A = detection limit not available
ng = 1.0E-09g
ug = 1.0E-06g
mg = 1.0E-03g
Standard conditions: 293 K (20 C) temperature and 1 atmosphere pressure.
8760 operating hours per year

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16. ABSTRACT

This report summarizes the results of a dioxin/furan emissions test of a sewage sludge incinerator equipped with a wet scrubber system for particulate matter emissions control. The test was the third in a series of thirteen dioxin/furan emissions tests conducted under Tier 4 of the National Dioxin Study. The primary objective of Tier 4 is to determine if various combustion sources are sources of dioxin and/or furan emissions. If any of the combustion sources are found to emit dioxin or furan, the secondary objective of Tier 4 is to quantify these emissions.

Sewage sludge incinerators are one of eight combustion source categories tested in the Tier 4 program. The tested sewage sludge incinerator, hereafter referred to as incinerator SSI-B, was selected for this test after an initial information screening and a one-day pretest survey visit.

Data presented in the report include dioxin (tetra through octa homologue + 2378 TCDD) and furan (tetra through octa homologue + 2378 TCDF) results for both stack samples and ash samples. In addition, process data collected during sampling are also presented.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Emissions Combustion Sources Dioxin Furans 2,3,7,8 Tetrachlorodibenzo-p-dioxin Sewage Sludge Incinerator Incineration	Air Pollution Emissions Data	
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